CTPS TECHNICAL REPORT

56b

HIGHLAND AVENUE/ NEEDHAM STREET CORRIDOR TRAFFIC STUDY: FUTURE CONDITIONS

July 1987

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ABSTRACT

This report documents the future-conditions portion of the Highland Avenue/Needham Street Corridor Traffic Study. Although released under separate cover, it complements CTPS Technical Report 56a, Highland Avenue/Needham Street Traffic Study: Existing Conditions (August 1986). The full study of corridor traffic conditions comprises both reports.

Presented in this report are land-use and traffic-volume forecasts for 1995. Traffic-volume assignments to the no-build and three alternative street networks were produced and analyzed in detail. The analysis indicated a potential for existing traffic-flow problems to persist and others to develop within the ten-year horizon. Each identified problem was considered under each network alternative, and, where necessary, other corrective actions were evaluated.

Recommendations are made to address the long-term traffic-operations needs of the corridor. To effect implementation of these recommendations, a cooperative effort among private, municipal, and state interests is considered essential.

This document was prepared by **CENTRAL TRANSPORTATION PLANNING STAFF**, an interagency transportation planning staff created and directed by the Metropolitan Planning Organization, consisting of the member agencies.

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Massachusetts Bay Transportation Authority
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1 INTRODUCTION

The Central Transportation Planning Staff (CTPS), under the direction of the Sub-Signatory Committee (SSC) of the Boston Metropolitan Planning Organization (MPO) and at the request of the Massachusetts Department of Public Works (MDPW), has undertaken a feasibility analysis of a proposed improvement plan for the Highland Avenue/Needham Street corridor in the Town of Needham and the City of Newton. This improvement plan, the "Highland Avenue/Needham Street Corridor Consensus Plan," was developed jointly by officials of the City of Newton, the Town of Needham, and the Newton-Needham Chamber of Commerce.

The CTPS analysis is in two parts. A study of short-term improvements has been documented in CTPS Technical Report 56a, Highland Avenue/Needham Street Corridor Traffic Study: Existing Conditions (August 1986). The present report analyzes proposed long-term improvements, both those recommended in the Consensus Plan and additional proposals developed by CTPS. The proposed improvements are generally large in scale, often involve land acquisition for right-of-way space, and require more than a year for completion of design and construction. The cost of these projects is substantial; funding is consequently a key determinant of the implementation timetable.

The following long-term recommendations from the Consensus Plan are evaluated in this report.

- Construction of a frontage road between the New England Industrial Center and Route 128, extending approximately from the Kendrick Street overpass to the exit 56E ramp.
- In conjunction with the frontage road, removal of the median barrier on Highland Avenue at First Avenue.
- Widening the Highland Avenue bridge from its present two-lane section to four lanes.
- An overall widening of Highland Avenue and Needham Street to provide four travel lanes and a continous, two-way, left-turn center lane from First Avenue in Needham to Winchester Street in Newton.
- Major modifications to the Winchester Street/Route 9 interchange.

In order to analyze the feasibility and potential of the Consensus Plan and CTPS recommendations and project how future demands will affect the corridor network, a series of traffic assignments were developed. Existing (1985) traffic volumes were assigned to the present network of streets and to the network which would exist if the recommendations were in place. Future-year (1995) traffic volumes were then developed for the present network on the basis of proposed and potential land-use developments. This future-year traffic was assigned to the present and the proposed long-range corridor networks. On the basis of these assignments, road-segment and intersection capacity was reevaluated, needs were identified, and alternative improvement measures were developed and assessed.

2 PROJECTED LAND-USE DEVELOPMENTS

By 1995, the land-use characteristics of the Highland Avenue/Needham Street corridor will have changed. The extent and nature of the change which takes place will depend on several factors:

- o Community land-use and zoning policies
- o Market forces
- o Individual land-owner decisions
- o Improvements in transportation and infrastructure

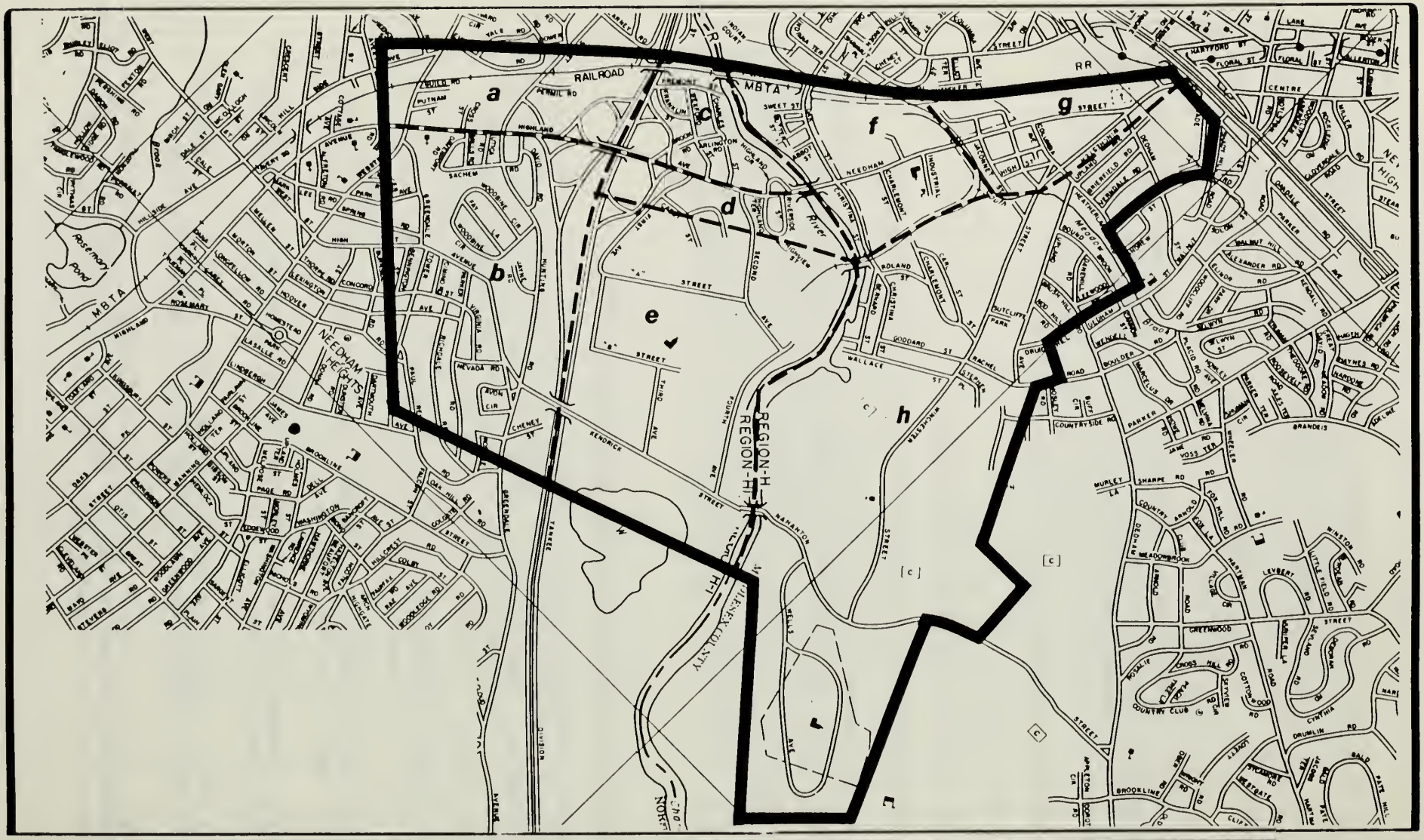
Each of these factors has been taken into consideration in forming a basis for projecting 1995 study-area land use. To facilitate this effort, the study area was divided into subareas of similar land-use strata, as shown in Figure 2-1. Needham was divided into five subareas, A through E, and Newton into three subareas, F through H. These subdivisions are consistent with those used in the land-use discussion in the existing-conditions report.

2.1 COMMUNITY LAND-USE POLICY AND EXPECTATIONS

Recent studies by both Needham and Newton have identified general and specific land-use policies which relate to the corridor study area. For Needham, land-use policy was most recently discussed in a document entitled, Planning Studies, 1983, published April 6, 1983, by the Needham Planning Board.

The future land-use policy described in this report, as it affects the study area, can be summarized as follows:

- o Land use in Needham is predominantly residential, both in fact and by policy choice.
- o Major change to the overall land-use pattern is neither likely nor desired.
- o Any major expansion of nonresidential uses will require more intensive redevelopment of already developed areas.
- o There is an existing policy that further intensification in industrial areas should be facilitated, contingent only upon demonstration of acceptable impacts, especially those on



Highland Avenue/Needham Street Traffic Study: Future Conditions	LAND USE SUBAREA BOUNDARY MAP	CTPS
Technical Report 56b July 1987		FIGURE 2-1

traffic. The Town chooses not to encourage more industrial area, so more intensive use is the only possible alternative.

- The reuse of properties along Gould Street will require careful planning to balance economic development and residential uses.

Since 1983, the Town of Needham has received several proposals from developers which, when totalled, would add some one million square feet of office and commercial space to the study area.

The City of Newton more recently studied the Needham Street corridor land-use issues in detail, with the assistance of Lozano, White & Associates. The findings have been documented in a report entitled, The Needham Street Corridor: Proposals for the Future (November 1984). The major conclusions and policy recommendations are as follows:

- The extensive warehouse space in the corridor is likely to be changed to higher-value uses, such as office and retail space.

- The attractiveness of the corridor for office space is reflected in current developments on Highland Avenue in Needham.

- The suitability of the corridor for additional retail use is evident from the success of the existing stores (e.g., Marshall's Plaza).

- Traffic conditions are poor in the corridor, but there are no firm plans for improvement. Retail stores, which thrive on traffic, may be more attractive to developers than office buildings.

- Only a few large parcels appear prime for development in the near future (e.g., St. Regis and New England Concrete Pipe). Other large sites have been locked up by long-term leases, acquisitions, and improvements. Assembly of smaller parcels is costly and takes time.

- Development of smaller properties is likely, both for offices and retail.

The report specified that development for the next eight to ten years can be anticipated as follows:

- St. Regis property: Access to Route 128 and ample size (17 acres) make the site a natural for large-scale office development. At least 680,000 sq. ft. could be developed here under existing zoning, with at-grade parking.

- o New England Concrete Pipe property: Ample size (8.5 acres) but limited frontage suggests such uses as retail (shopping center) or an owner-developed office building. Some 370,000 sq. ft. of office space could be developed here with at-grade parking, with as much as 700,000 sq. ft. possible with a parking structure. Alternatively, a shopping center of 150,000 sq. ft. could be built.

- o Smaller parcels: Projects totalling 285,000 sq. ft. are now in the planned or rumored stages.

- o If the St. Regis and the New England Concrete Pipe properties were redeveloped, and other planned projects went ahead, a total of at least 1.3 million sq. ft. of office space could be constructed in the corridor.

2.2 INFRASTRUCTURE CONCERNS

In Newton's study of land-use in the Needham Street corridor, the point is made that the existing capacity of the sewer system is not adequate for the amount of additional development expected, and that this will be a major factor in the amount of development which can occur in the corridor over the next ten years. It is unclear whether there are similar problems in Needham; however, sufficient sewer capacity for the anticipated level of development can be provided through reconstruction of the Charles River interceptor. No schedule has yet been set for this replacement.

2.3 PROJECTIONS OF 1995 LAND USE BY SUBAREA

On the basis of existing land use, proposed and expected development, community policies, and an assumed continuation of market pressure for further development through 1995, forecasts of land use were prepared for each of the eight corridor subareas. These forecasts are presented in Table 2-1; for each subarea, projections for residential, office, retail, and manufacturing uses are given, and uses which do not fall precisely into one of these categories are also specified. Changes in residential use are given in terms of dwelling units, while changes in office, retail and manufacturing use are given in square feet.

For subarea A in Needham, three proposals for office buildings had been submitted to the Town as of 1984. The racquetball, Muzi Ford, and Red Ball buildings are expected to be redeveloped into offices by 1995. A net decrease in retail space of over 75 percent is expected, but 5,000 sq. ft. of new retail space is anticipated.

Subarea A	Existing 1983	Projected 1995
Residential	58 units	58 units
Office	148,832 sq. ft.	604,832 sq. ft.
Retail	40,142 sq. ft.	7,422 sq. ft.
Manufacturing	28,560 sq. ft.	9,240 sq. ft.
Racquetball	27,167 sq. ft.	
Subarea B		
Residential	457 units	457 units
Office	5,922 sq. ft.	5,922 sq. ft.
Retail	0	0
Manufacturing	0	0
Subarea C		
Residential	12 units	0 units
Office	168,521 sq. ft.	347,371 sq. ft.
Retail	97,645 sq. ft.	100,145 sq. ft.
Manufacturing	221,809 sq. ft.	171,809 sq. ft.
Subarea D		
Residential	43 units	43 units
Office	26,010 sq. ft.	64,260 sq. ft.
Retail	49,086 sq. ft.	53,086 sq. ft.
Manufacturing	52,880 sq. ft.	52,880 sq. ft.
Subarea E		
Residential	0 units	0 units
Office	525,321 sq. ft.	716,721 sq. ft.
Retail	228,976 sq. ft.	202,756 sq. ft.
Manufacturing	2,112,348 sq. ft.	2,366,742 sq. ft.
Hotel	43,100 sq. ft.	86,200 sq. ft.
Needham Summary		
Residential	570 units	558 units
Office	874,606 sq. ft.	1,739,106 sq. ft.
Retail	415,849 sq. ft.	363,409 sq. ft.
Manufacturing	2,415,597 sq. ft.	2,600,671 sq. ft.
Racquetball	27,167 sq. ft.	0
Hotel	43,100 sq. ft.	86,200 sq. ft.

Subarea F	Existing 1983	Projected 1995
Residential	77 units	77 units
Office	98,962 sq. ft.	631,462 sq. ft.
Retail	186,469 sq. ft.	203,969 sq. ft.
Manufacturing	985,221 sq. ft.	555,221 sq. ft.
Subarea G		
Residential	50 units	50 units
Office	299,091 sq. ft.	520,591 sq. ft.
Retail	111,061 sq. ft.	202,756 sq. ft.
Manufacturing	191,747 sq. ft.	264,647 sq. ft.
Subarea H		
Residential	402 units	514 units
Office	644,725	769,725 sq. ft.
Retail	5,753	5,753 sq. ft.
Manufacturing	319,547	519,547 sq. ft.
Jewish Community Campus:		
Housing	99 units	99 units
Other	123,000 sq. ft.	145,000 sq. ft.
Newton Summary		
Residential	529 units	641 units
Office	1,042,778 sq. ft.	1,921,778 sq. ft.
Retail	303,283 sq. ft.	412,478 sq. ft.
Manufacturing	1,496,515 sq. ft.	1,339,415 sq. ft.
Jewish Community Campus:		
Housing	99 units	99 units
Other	123,000 sq. ft.	145,000 sq. ft.
Study Area Totals		
Residential	1,099 units	1,199 units
Office	1,917,384 sq. ft.	3,660,884 sq. ft.
Retail	719,132 sq. ft.	775,887 sq. ft.
Manufacturing	3,912,112 sq. ft.	3,940,086 sq. ft.
Racquetball	27,167 sq. ft.	0
Hotel	43,100 sq. ft.	86,200 sq. ft.
Jewish Community Campus:		
Housing	99 units	99 units
Other	123,000 sq. ft.	145,000 sq. ft.

Highland Ave./Needham St.: Future Conditions Technical Report 56b July 1987	LAND USE BY SUBAREA, EXISTING AND PROJECTED	CTPS TABLE 2-1b

No changes are anticipated in Needham's largely residential and nearly fully developed subarea B.

Subarea C, the north side of Highland Avenue east of Route 128, is expected to undergo substantial redevelopment by 1995. The twelve residential units are expected to be redeveloped as offices and supporting retail establishments. As of 1984, the Town had received four proposals for office buildings in this area. Several small manufacturing and retail sites are also expected to be reassembled as larger parcels suitable for office buildings.

On the opposite side of Highland Avenue from subarea C, subarea D occupies the strip of land immediately north of the New England Industrial Center. No change is anticipated in the amount of residential or manufacturing use by 1995. Retail use will be increased by the expansion of Berijik Olds currently underway. Office development is also expected to increase; two proposals for office buildings in this area had been received by the Town as of 1984.

Subarea E encompasses the New England Industrial Center. Though the NEIC is primarily a manufacturing center, in recent years office use has begun to appear through redevelopment of manufacturing space. While manufacturing developments are expected to continue in the foreseeable future, the mix of use will change, as office buildings become more common and a 36,000 sq. ft. hotel is opened.

Subarea F is located in Newton, north of Needham Street, and extends from west to east between the Charles River and the railroad tracks. Projects already underway or under consideration by the City include office-building construction and expansion, and two new retail establishments. Conversion of the Saint Regis paper plant into approximately 400,000 sq. ft. of office space is anticipated by 1995.

Continuing to the east on Needham Street and terminating at Route 9 on Winchester Street, subarea G is currently experiencing new demands for additional office space. By 1995, the New England Concrete Pipe facility is expected to be redeveloped into a mixed-use office and retail complex. Certain other small manufacturing sites are also expected to be reconverted into retail and possibly office developments. The residential section is expected to be unchanged.

Finally, subarea H lies along Winchester Street and includes the Office Park at Route 128, the Jewish Community Campus, and a portion of the Charles River Country Club. Residential neighborhoods predominate in this section of the study area, and proposals for continued residential development are presently under review by the City. The remaining vacant land in the Office Park at Route 128 is also expected to be developed by 1995, and should

include both manufacturing (R&D) and office buildings. Directly opposite the office park on Nahanton Street is the Jewish Community Campus, a complex of residences, offices, sports facilities, and day care and nursery school facilities, which was fully operational by the end of 1985. An addition to the complex of as much as 25 percent is expected by 1995.

Overall, the pressure for continued development is expected to remain high within the study area through the 1995 horizon year. However, the demand for new office space will be greater than all others and will cause the continuation of the recent trend toward the conversion of manufacturing and residential uses into office space. In total, better than 2,000,000 sq. ft. of new commercial and industrial development can be expected by 1995 in the area at large.

3 TRAFFIC-VOLUME FORECASTS

Traffic-volume forecasts were produced for the study area under five network scenarios: the 1983-84 base case, 1995 no-build, and three 1995 build scenarios (Frontage Road, Service Road, and Frontage/Service combined, which are discussed in sections 3.3, 3.4, and 3.5).

3.1 FORECASTING PROCEDURE

Forecasts of future-year 1995 average daily traffic volumes for the study corridor were developed using procedures outlined in National Cooperative Highway Research Program Report Number 187, "Quick Response Urban Travel Estimation Techniques and Transferable Parameters."

The information necessary for the use of this technique includes the number of corridor-area households, retail-sector employees, and total employees. Base-year 1985 and future-year 1995 estimates of households and employment were developed from the base-year inventory and 1995 forecasts of residential units and commercial area square footage presented in Table 2-1.

Base-year 1985 estimates of households and of retail and total employment were used to derive a synthetic origin-and-destination (O/D) matrix of corridor area trips. The O/D matrix was then assigned to a representative network of corridor roadways. Assigned volumes were subsequently compared to actual counts of intersection turning movements and road-segment volumes; adjustments were made to the network and O/D matrix to calibrate the assigned volumes to the actual counts.

Future-year traffic volumes were similarly produced. Returning to the first step of the process, future-year forecasts of employment and households as developed and discussed above were entered to generate a future-year 1995 O/D matrix. This O/D matrix was assigned to the previously calibrated base network. Once a satisfactory future-year assignment was produced, network changes were introduced to simulate the effect of alternatives on area traffic.

3.2 BASE-CASE NO-BUILD NETWORK ASSIGNMENTS

A comparison of 1983-1984 and 1995 24-hour average daily traffic (ADT) volumes is presented for selected segments of the

base-case corridor network in Table 3-1. The 1983-1984 ADT volumes listed are actual ground counts reported by the MDPW and CTPS which appeared in the existing-conditions report. The estimated 1995 ADT volumes presented were produced by factoring the 1983-1984 volumes by the differences which were found to exist between the 1983-1984 and 1995 network assignments discussed in section 3.1. The result is "adjusted" 1995 volumes. The 1995 ADTs, therefore, reflect the effects which area land-use developments through 1995 are likely to have on corridor traffic demand. Overall, these assignments indicate annual increases in study-area traffic volumes of between 1.96 and 3.54 percent, with most increases expected to be greater than 2.5 percent per year.

As shown in the table, these increases have the potential to add from 9,000 to 14,000 vehicle-trips per day to the Winchester Street/Needham Street/Highland Avenue strip between Route 9 in Newton and Webster Street in Needham. Traffic is expected to increase most on Highland Avenue near the Route 128 interchange. Ongoing development, particularly in the New England Industrial Center and in the Highland Avenue/Gould Street commercial district, is expected to add 12,000 to 15,000 vehicles per day to the studied section of Highland Avenue by 1995.

Needham Street and Winchester Street land use developments, largely confined to a 200-foot commercial zone on either side of the road, are likely to add between 8,000 and 9,000 vehicles per day in Newton.

On the southern side of the study area, further development of Wells Avenue, completion of the Jewish Community Campus, and further expansion within the New England Industrial Center are expected to cause slightly smaller increases in volume, on Nahanton Street and Kendrick Street. On Nahanton Street, 1995 ADTs are expected to reach 20,000 from the addition of 5,000 vehicle-trips per day in the area. On Kendrick Street in Needham, volume is expected to increase by 4,000 vehicles per day, bringing ADT totals to 18,400 by 1995.

Among secondary streets, the Gould Street/Hunting Road section is expected to experience the highest growth increases, and reach an average of approximately 14,400 vehicles per day on each road by 1995. First Avenue and Second Avenue taken together are expected to serve an additional 5,000 vehicles per day. On Oak Street and Christina Street, ADT volumes should increase by 3,000 and 300 vehicles per day, respectively. Finally, Dedham Street at Winchester Street should experience volume increases of 1,500 vehicles per day over the 11-year period.

3.3 FRONTAGE ROAD NETWORK ALTERNATIVE

The possibility of constructing a frontage road between the New England Industrial Center and Route 128, from approximately

	Observed 1983-1984 Base-Case	Estimated 1995 No-Build	11-Year Growth Rate	Annual Compound Rate
Highland Avenue				
between First Ave and Wexford St	33000	47500	44.50	3.40
west of Route 128	32250	44500	38.80	3.03
Needham Street				
east of Oak St and Christina St	28500	37000	31.70	2.53
east of Columbia Ave	24300	33000	35.80	2.82
Winchester Street				
south of Route 9	25000	33600	34.40	2.72
Kendrick Street				
west of Third Ave	14150	18400	30.28	2.43
Nahanton Street				
east of Wells Ave	14700	20000	35.36	2.79
Gould Street				
at Highland Ave	10500	14400	37.43	2.93
Hunting Road				
at Highland Ave	7900	10300	30.94	2.48
Second Avenue				
at Highland Ave	10500	13000	23.74	1.96
Oak Street				
at Needham St	5700*	8400	46.68	3.54
Christina Street				
at Needham St	2400	2700	12.25	1.06
Dedham Street				
at Needham St	4500*	6100	35.02	2.77

*CTPS estimate

Highland Ave./Needham St.: Future Conditions	AVERAGE DAILY TRAFFIC VOLUME 1983-84 BASE CASE AND 1995 NO-BUILD	CTPS TABLE 3-1
Technical Report 56b July 1987		

Kendrick Street to Route 128 exit 56E on Highland Avenue, was among the network modifications simulated under future-year traffic. The frontage road alternative as analyzed would operate one-way northbound, and provide slip-ramp access from Kendrick Street and Route 128 northbound to the New England Industrial Center. The configuration of the frontage road alternative is shown in Figure 3-1. Direct access to the industrial center would be possible by extending "A" Street to create an "A" Street/Frontage Road intersection. The northern terminus of the frontage road would merge with the present exit 56E ramps in the southeastern quadrant of the interchange, to permit frontage road movements onto Highland Avenue and Route 128.

Assuming that a frontage road were operational by 1995, vehicle demand for such a facility would be expected to reach 17,000 vehicles per day (refer to Table 3-2). Approximately 10,500 vehicles would enter from Route 128, and the remaining 6,500 would enter from Kendrick Street. Of these, some 3,600 vehicles would enter the industrial center directly from the frontage road on the "A" Street connection. Approximately 2,000 vehicles per day would use the frontage road to reach the Route 128 northbound entrance ramps at exit 56E.

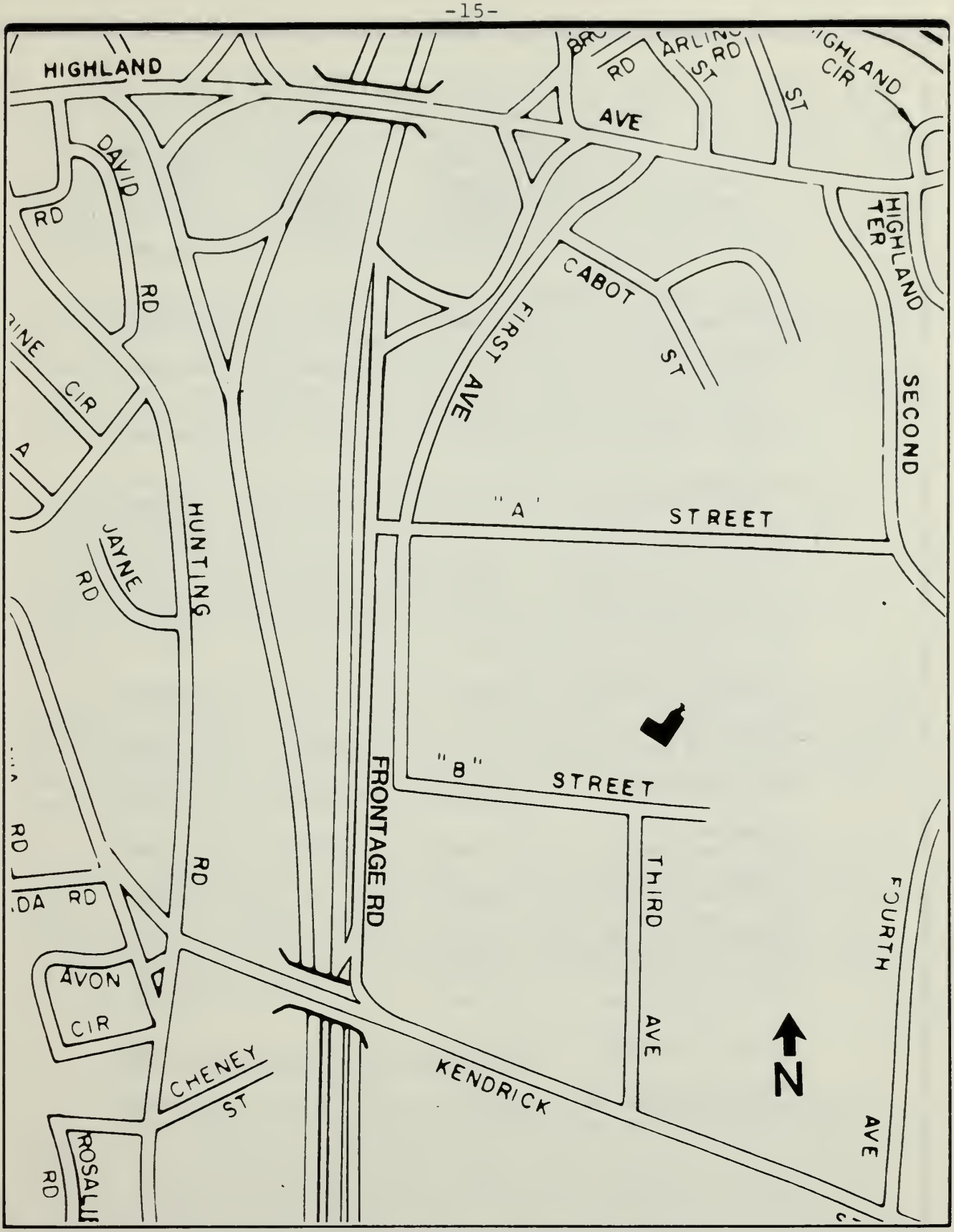
The introduction of a frontage road could be expected to reduce 1995 Highland Avenue daily traffic volumes by 7,000 vehicles between the Route 128 ramps and First Avenue. These reductions would result from the diversion of four categories of traffic to the frontage road.

- Route 128 traffic which under base-case conditions exits the industrial center on Second Avenue would, with this frontage road configuration, have the ability to exit the industrial center on an "A" Street connection to the frontage road to reach northbound Route 128.

- Other Route 128 (northbound) traffic, which in the base case exits the industrial park on First Avenue and reverses direction on Highland Avenue at Wexford Street to reach Route 128, would also have the option of exiting the industrial center directly on the frontage road entrance ramp to Route 128 north.

- Route 128 northbound traffic which in the base case uses exit 56E to reach the industrial park on First Avenue and, to a lesser extent, Second Avenue, would instead use the new Route 128 entrance to the frontage road to reach the industrial center.

- Kendrick Street traffic which in the base case crosses the industrial center on Fourth Avenue and Second Avenue to westbound Highland Avenue and thence to Route 128 northbound, would instead access the frontage road directly from Kendrick Street to reach Route 128 northbound.



Highland Ave./Needham St.: Future Conditions	PROPOSED LOCATION OF FRONTAGE ROAD AND SLIP RAMPS	CTPS
Technical Report 56b July 1987		FIGURE 3-1

Location	Frontage Road	Service Road	Frontage Road & Service Road
Route 128 NB North of Kendrick St	-10,500	0	+10,500
Frontage Road NB South of "A" St Connection	+17,000	0	+17,000
Service Road EB East of First Avenue	0	+4,300	+ 4,300
Highland Avenue Between Route 128 and First Avenue	- 7,000	0	- 8,000
Highland Avenue EB Between Hunting Road and Route 128	- 4,000	0	- 4,000
Highland Avenue WB Between Second Avenue and Charles Street	- 2,500	+2,400	- 100
Highland Avenue EB East of First Avenue	- 1,200	-2,400	- 3,600
Hunting Road NB Between Kendrick St and Highland Avenue	- 4,000	0	- 4,000
First Avenue SB @ Highland Avenue	- 2,500	+2,400	- 1,100
Second Avenue SB @ Highland Avenue	- 1,200	0	- 1,200
Second Avenue NB @ Highland Avenue	- 4,100	+2,500	- 1,600
Kendrick Street WB West of Third Avenue	+ 3,300	0	+ 3,300
Kendrick Street EB West of Frontage Road	+ 4,200	0	+ 4,200
Third Avenue SB South of "B" Street	+ 2,000	0	+ 2,000
Fourth Avenue SB South of "A" Street	- 1,000	0	- 1,000
Fourth Avenue NB North of Kendrick St	- 2,500	0	- 2,500

Highland Ave./Needham St.: Future Conditions Technical Report 56b July 1987	AVERAGE DAILY TRAFFIC VOLUME IMPACT OF NETWORK ALTERNATIVES - 1995	CTPS TABLE 3-2

A portion of the traffic originating on Kendrick Street also uses Hunting Road and Highland Avenue to reach northbound Route 128. Other traffic is also generated along the Hunting Road path from the residential areas bordering Greendale Avenue. With the availability of the frontage road, this traffic would use Kendrick Street to directly access Route 128 northbound, and the reduction in Hunting Road northbound volumes would be as much as 4,000 vehicles per day by 1995.

The reduction in use of the northbound Route 128 ramp to eastbound Highland Avenue in favor of frontage road access to the New England Industrial Center would be expected to reduce First Avenue and Second Avenue southbound (entering) volumes, respectively, by as much as 2,500 and 1,200 vehicles per day. Frontage road access to Route 128 would also cause a 2,500-vehicle-per-day reduction in Second Avenue northbound volumes.

On Kendrick Street, 1995 westbound traffic approaching the frontage road ramp could potentially increase by better than 3,000 vehicles per day. A similar increase of 3,500 daily vehicles could be expected on the eastbound Kendrick Street approach to the frontage road ramps. This would be beneficial, as it takes advantage of the excess capacity available on Kendrick Street by transferring a portion of Highland Avenue traffic from a section where volumes approach capacity.

Third Avenue and Fourth Avenue southbound volumes would be expected to experience a combined increase of better than 3,000 vehicles per day in response to the presence of a frontage road. At the same time, northbound Fourth Avenue traffic headed for Second Avenue and Route 128 could decline by 2,500 vehicles per day in favor of frontage road access.

These findings indicate that the frontage road alternative has the potential to lower traffic volumes on the most critical road section in the study-area corridor: Highland Avenue between Route 128 and Second Avenue. Daily traffic volumes could be reduced by as much as 7,000 vehicles per day. A frontage road would also cause traffic levels to decline to the west of Route 128, on Hunting Road.

3.4 SERVICE ROAD NETWORK ALTERNATIVE

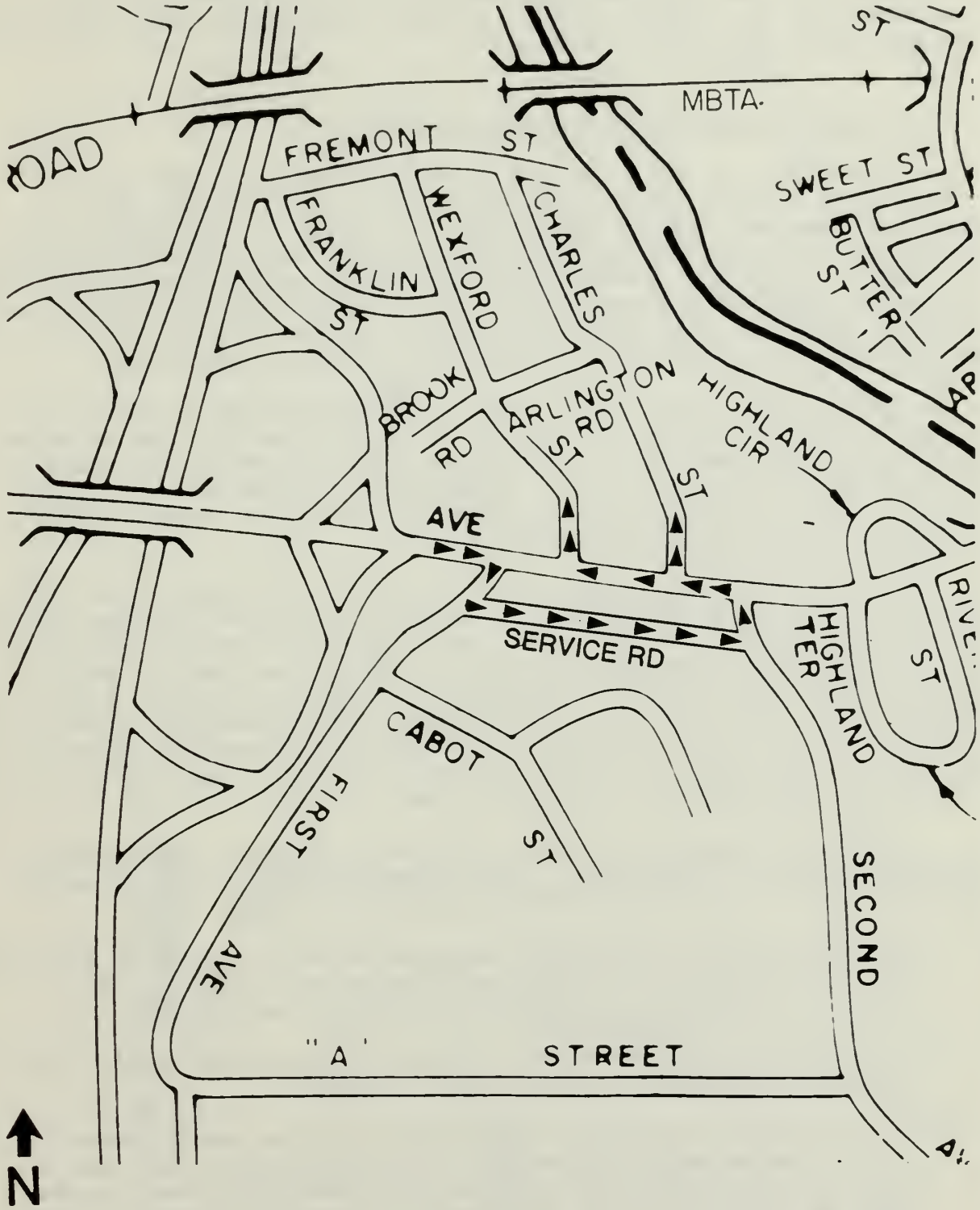
Present and future traffic conditions on Highland Avenue between the Route 128 ramps and Second Avenue will be unstable due to the presence of a persistent need for access to the Wexford Street/Charles Street commercial area on the northern side of Highland Avenue. Traffic entering Wexford Street or Charles Street from the west must make a difficult left turn from eastbound Highland Avenue. To leave the area in the direction of Newton (easterly), an even more difficult left turn from either Wexford Street or Charles Street is necessary.

The difficulty in executing left turns is caused by the volume of through traffic, which takes precedence over left turns and blocks competing turn movements. Left turns from Highland Avenue also take precedence over the lefts from secondaries like Wexford and Charles streets, further complicating the problem. The service road alternative would eliminate left turns to the north side of Highland Avenue by channeling all such traffic onto First Avenue, the service road, and Second Avenue to westbound Highland Avenue, from which movements onto Wexford and Charles streets, and other northbound movements, could be made as right turns (refer to Figure 3-2). Serving as an extended jug handle, this alternative would lessen the traffic-blocking effect of the Highland Avenue traffic on side-street movements.

As of the 1995 forecast year, use of the service loop facility would be expected to average 4,300 vehicles per day. Included within this total are 2,300 trips from eastbound Highland Avenue to Wexford Street and/or Charles Street which would be channeled to westbound Highland Avenue as discussed above. Another 2,000 vehicles per day would use the service road to exit the industrial center from the northwestern quadrant. Under present conditions, this traffic must access Second Avenue from "A" Street in order to exit the center onto westbound Highland Avenue. Overall, the only additional Highland Avenue traffic resulting from this action would be 2,300 right turns destined for Wexford Street or Charles Street.

Present-day safety problems at Wexford Street exist in part because of U-turn violations at the median terminus east of First Avenue on Highland Avenue. Although the actual number of U-turns and left turns into Wexford Street from First Avenue/Highland Avenue has not been field-checked, it is clear that a certain percentage of the traffic exiting the industrial center finds it more convenient to exit at First Avenue and reverse direction once on Highland Avenue, than to exit from Second Avenue. The presence of the service road will improve the accessibility of the Second Avenue exit from First Avenue and permit First Avenue to be closed as an exit from the industrial center. This would minimize the need for enforcement at the median terminus and would cause all traffic destined for westbound Highland Avenue to use Second Avenue to exit the industrial center, as originally intended when the Highland Avenue median was extended beyond First Avenue.

As documented in the existing-conditions report, Highland Avenue/Second Avenue intersection operations are frequently affected by the downstream blockages which occur during the PM-peak period. The prohibition of all left turns, which would be made possible by the construction of a service road/jug handle, would eliminate that portion of downstream (west of Second Avenue) disruptions caused by left turns being made into Charles Street and Wexford Street from Highland Avenue.



Highland Ave./Needham St.: Future Conditions	SERVICE ROAD CIRCULATION PATTERN WITH LEFT TURN PROHIBITION ON HIGHLAND AVENUE E.B.	CTPS
Technical Report 56b July 1987		FIGURE 3-2

The elimination of these left turns by channeling that traffic onto the service road results in 2,500 additional vehicles per day (VPD) on Second Avenue northbound and 2,400 VPD on westbound Highland Avenue.

3.5 FRONTAGE ROAD/SERVICE ROAD COMBINED

Provision of the frontage road together with the service road would further change circulation patterns within the Highland Avenue section of the corridor area. Route 128 northbound traffic exiting onto Highland Avenue eastbound would benefit most. Both the eastbound volumes on Highland Avenue between Route 128 and First Avenue and the volumes on the frontage road ramp to Highland Avenue would be lower than under a no-build condition or with either the frontage or service road alone.

As shown in Table 3-2 (above), Highland Avenue traffic between Route 128 and First Avenue would be lower by approximately 8,000 vehicles per day if a service road were built in conjunction with the frontage road. This reduction is 1,000 vehicles per day greater than would be expected from the construction of a frontage road without the service road.

The availability of both facilities would allow Route 128 northbound traffic destined for Wexford Street or Charles Street to exit onto the frontage road, use the "A" Street connection to First Avenue northbound, and enter the service road directly rather than use the ramps to Highland Avenue eastbound (refer to Figure 3-3). It would also better facilitate access to the commercial area on the northside of Highland Avenue than would the service road without a frontage road, particularly for the Route 128 northbound movement into the area.

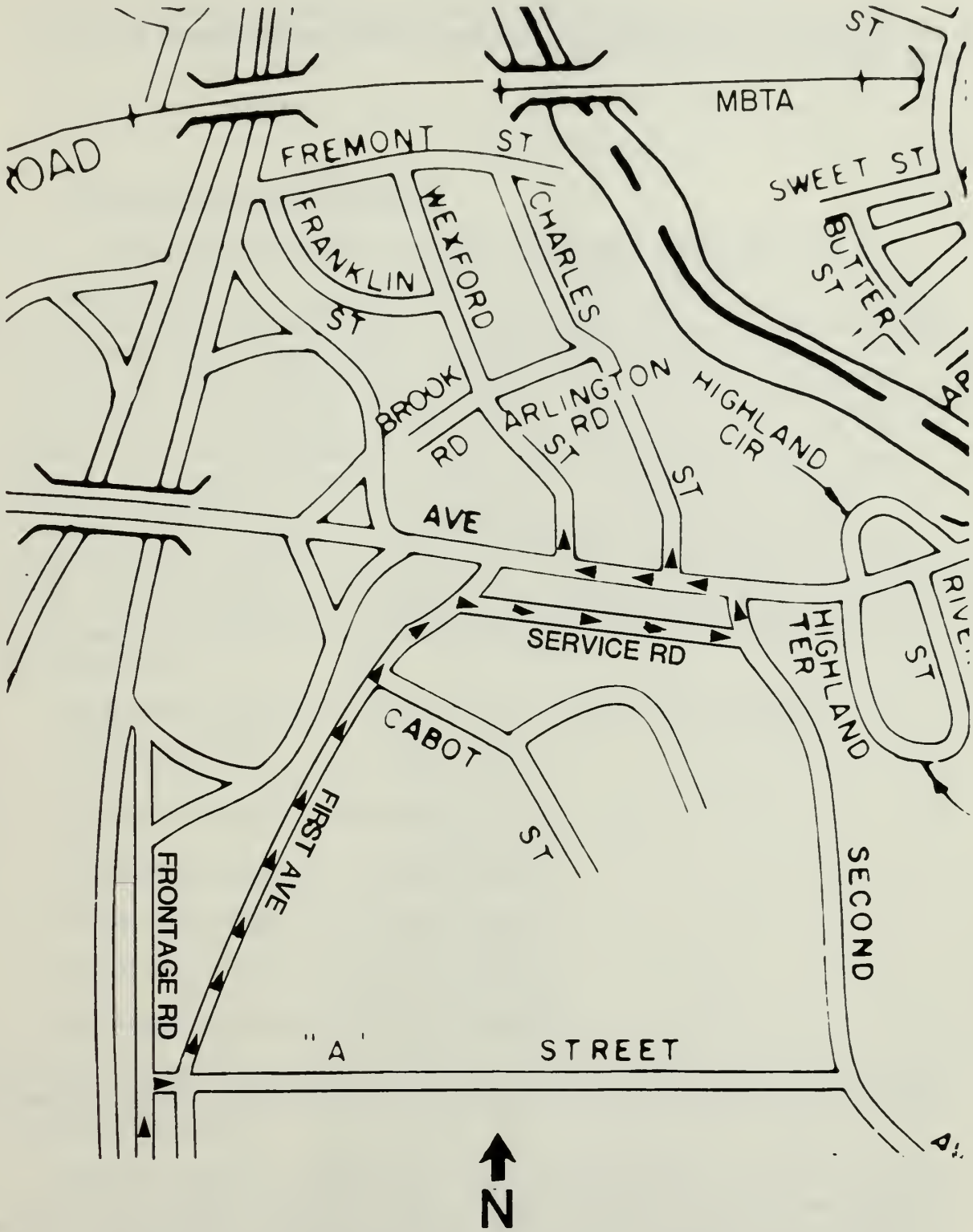
On other roadway sections, the frontage road and service road each tend to complement and counter-balance the influences of the other. With both facilities operational by 1995:

- Highland Avenue westbound between Second Avenue and Charles Street would be influenced only marginally due to the mutually offsetting effects of the two facilities.

- Highland Avenue eastbound east of First Avenue would net a 3,600-vehicle-per-day decline in volume.

- First Avenue southbound at Highland Avenue would experience a decline of approximately 1,100 vehicles per day, due in part to the Route 128 northbound volume that would access the service road from the frontage road/"A" Street connection to First Avenue.

- Second Avenue traffic northbound at Highland Avenue would be expected to decline by a total of 1,600 vehicles per day.



Highland Ave./Needham St.: Future Conditions	CIRCULATION FROM RTE 128 NB TO WEXFORD STREET AND CHARLES STREET USING FRONTAGE ROAD TO SERVICE LOOP	CTPS FIGURE 3-3
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The potential of this network and of the other network alternatives to address future-year capacity problems is evaluated in the following chapter.

4 PERFORMANCE ANALYSIS OF ALTERNATIVE NETWORKS

4.1 INTERSECTION PERFORMANCE

4.1.1 Intersections Affected by the Build Alternatives

The frontage road and service road alternatives discussed above have differing effects on the performance of area roadway and intersection operations. Highland Avenue and Needham Street function as urban arterials within the corridor study area. By definition, the service volume capacity of such facilities is controlled by intersection capacity. This is due to the frequency of intersections and other side frictions along the arterial which interfere with traffic movements and limit the operational capacity of the facility. It is, therefore, necessary to evaluate the performance of the three networks (frontage road, service road and frontage road/service road) in terms of the respective impacts of each on intersection performance. The study-area intersections directly influenced by the addition of a frontage road and/or service road to the existing network are:

Highland Avenue at Gould Street and Hunting Road

Highland Avenue at First Avenue

Highland Avenue at Wexford Street

Highland Avenue at Second Avenue

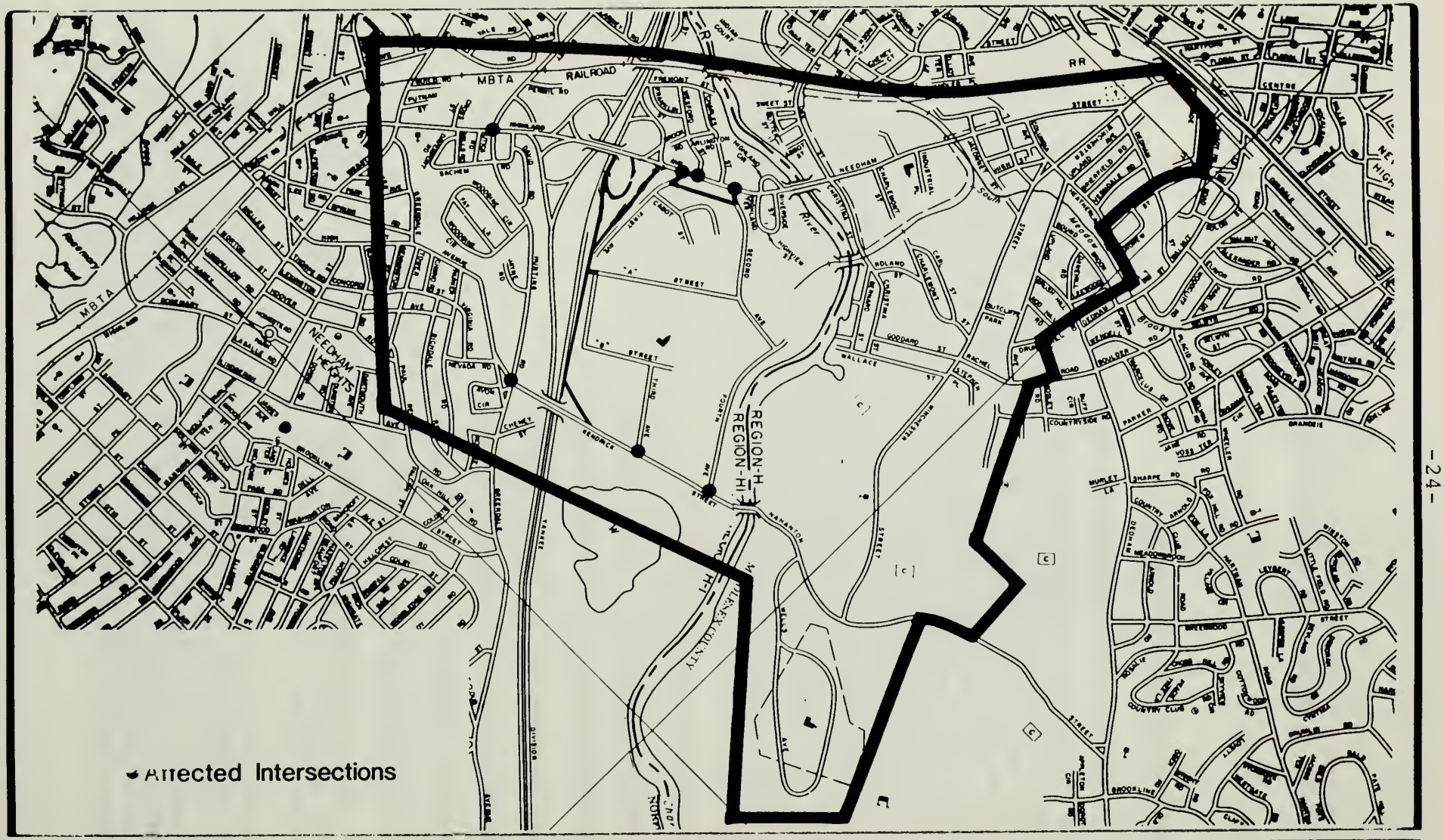
Kendrick Street at Fourth Avenue

Kendrick Street at Third Avenue

Kendrick Street at Hunting Road

Each of these locations is designated on Figure 4-1, which also shows the proposed locations of the frontage road and service road alternatives.

Future traffic operations were evaluated at each intersection on the basis of the 1995 traffic assignments developed for each of the future-year network alternatives (refer to Table 4-1). Assumed for analysis purposes was that the intersection improvement recommendations suggested in the existing-conditions report were implemented as of 1995. In those instances where recommended improvements did not provide acceptable levels of



Highland Avenue/Needham Street Traffic Study: Future Conditions Technical Report 56b July 1987	INTERSECTIONS AFFECTED BY TRAFFIC DIVERSION IMPACTS OF FRONTAGE ROAD AND SERVICE ROAD ALTERNATIVES	CTPS FIGURE 4-1

	No-Build	Frontage Road	Service Road	Frontage Road and Service Road
Highland Avenue @ Gould Street & Hunting Road (No modifications to intersection)	F	F	F	F
Highland Avenue @ First Avenue (No modifications to intersection)	E	F	N/A	N/A
Highland Avenue @ Wexford Street (No modifications to intersection)				
o Left turns from Highland Avenue	F	F	F	F
o Left turns from Wexford Street	F	F	F	F
Highland Avenue @ Second Avenue (One exclusive left-turn, two through lanes on Highland Avenue westbound, two left-turn lanes, one right-turn lane on Second Avenue)	D	C	E	C
Nahanton Street @ Jewish Community Campus & Wells Avenue Improvement plans are incomplete/				
Kendrick Street @ Fourth Avenue (Fourth Avenue one-way northbound, left from Kendrick Street)	D	D	D	D
Kendrick Street @ Third Avenue (Third Avenue one-way southbound, signal installed)	E	F	E	F
Kendrick Street @ Hunting Road (No modifications to intersection)	D	E	D	E

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LEVEL OF SERVICE ANALYSIS SUMMARY - INTERSECTIONS AFFECTED BY FRONTAGE ROAD AND SERVICE ROAD ALTERNATIVES 1995

CTPS

TABLE 4-1

service and where other improvement actions were readily apparent, these other improvements were assumed instead.

Highland Avenue at Gould Street and Hunting Road

Future-year traffic operations are expected to be poor at this intersection regardless of the network alternative. The reason for the poor performance is primarily the high volume of left-turning traffic exiting Gould Street during the PM peak hour. Under present (1985) conditions, similar levels of service were confirmed in the level of service analysis completed for the existing-conditions report. However, field checks indicate that the intersection is actually operating below possible capacity: the presence of two exit lanes on Highland Avenue eastbound permits left-turning traffic to exit Gould Street without conflict or cycle failure. The analysis, therefore, does not provide a definitive evaluation of the condition of operations at this particular location, and traffic flow should be periodically field-checked to determine if excessive delay and cycle failure become a permanent problem.

Highland Avenue at First Avenue

Under the no-build alternative, right turns made from First Avenue to Highland Avenue will be subject to long delay (level of service E in 1995), due to the expected increases in volume on both First Avenue and Highland Avenue and to the blocking effect which through traffic on Highland Avenue will have on First Avenue.

The frontage road alternative provides a higher level of service (C) than does the no-build alternative to right-turning traffic moving from First Avenue. The higher level of service results from the lower volume of through traffic eastbound on Highland Avenue past the intersection. The lower traffic volume results from the diversion of the Route 128 northbound traffic that presently enters the New England Industrial Center on Second Avenue, to the Frontage Road for entry to the industrial center on "A" Street.

The service road and frontage road/service road alternatives both include a provision to prohibit access to Highland Avenue from First Avenue. This eliminates all intersection conflict points at Highland Avenue and First Avenue, causing the level of service at this point to be entirely dependent on the downstream operational condition of the Highland Avenue/Second Avenue intersection and other Highland Avenue locations further east.

Highland Avenue at Wexford Street

The analysis of future-year traffic operations at this intersection indicates that none of the frontage road or service road alternative configurations provides sufficient diversion of

traffic to cause an improvement in service levels. The high volume of peak-period westbound traffic on Highland Avenue at Wexford Street uses all available capacity, subjecting all other (major and minor street) left-turn movements to excessive delays (level of service F).

Significantly, actions such as adding through or left-turn lanes to Highland Avenue and/or signalizing the intersections do not change the level of service findings. An increase in the number of lanes on Highland Avenue necessarily requires longer gap times for crossing traffic to traverse the added distance of the new lanes. As traffic volumes are expected to remain relatively low on Wexford Street for the foreseeable future, actions such as increasing the number of lanes or the lane widths also have no appreciable effect on intersection level of service ratings.

Similar problems exist at the Highland Avenue/Charles Street intersection. Peak-period problems are, however, slightly more difficult at Charles Street due to the Highland Avenue eastbound queues at the Second Avenue signal, which usually extend past the Charles Street approach to Highland Avenue and block all left-turning movements from Charles Street to Highland Avenue eastbound. With higher traffic volumes anticipated on Highland Avenue in the future, this condition is expected to worsen.

The continued existence of failing levels of service at each of these intersections in the years following the construction of the frontage road and/or service road means that additional steps will be required if traffic operations are to function acceptably in the future. Of equal importance is the consideration that the problems at these intersections, owing to their proximity to the Highland Avenue/Second Avenue intersection, can cause a disruption of vehicle operations on northbound Second Avenue and westbound Highland Avenue.

Highland Avenue at Second Avenue

The results of the traffic operations analysis at Highland Avenue and Second Avenue indicate the high sensitivity of this location to the introduction of a frontage road or service road into the present system. Assuming that an exclusive left-turn lane can be added to the Highland Avenue westbound approach and that the Second Avenue (northbound) approach can be restriped as a double left turn/one exclusive right turn, the no-build condition in 1995 should operate as level of service D.

With frontage road access to and from the New England Industrial Center, the burden on Second Avenue to carry all exiting traffic from the area to the Route 128 ramp system will be lessened, as "A" Street access to the frontage road will serve a portion of the volume that would otherwise use Second Avenue as the only logical alternative. Level of service would increase to C.

The additional traffic that would be channeled onto Second Avenue if a service road were constructed without the benefit of a frontage road would reduce the 1995 service level of the intersection to E. However, if a frontage road/service road project were completed in 1995, the traffic-reducing effect of the frontage road/"A" Street connection on Second Avenue volumes would serve to offset the additional volumes of traffic on Second Avenue caused by the service road, and level of service C operations would be maintained.

Kendrick Street at Fourth Avenue

Creating a one-way Fourth Avenue entrance/Third Avenue exit pair on the south side of the New England Industrial Center would cause Fourth Avenue/Kendrick Street intersection operations to be dependent on the capacity available for eastbound left turns from Kendrick Street onto Fourth Avenue. Under each of the Frontage Road/Service Road alternatives, this left turn would operate at level of service D.

Kendrick Street at Third Avenue

Signalized and carrying all traffic exiting the New England Industrial Center to the south, Third Avenue would experience higher volumes of traffic under each of the frontage road alternatives than would be the case under the no-build or service road alternatives. This would occur as traffic in the southern quadrants of the industrial center heading for Route 128 northbound would exit via Third Avenue and reach the frontage road from Kendrick Street, rather than use the "A" Street connections to the frontage road. This additional traffic at the intersection has the potential to cause excessive delays unless additional intersection improvements are made in conjunction with the frontage road construction.

Kendrick Street at Hunting Road

The frontage road alternatives also have the potential to add traffic to this intersection, as traffic from the residential sections of Needham and from the south along Greendale Avenue divert to Kendrick Street in order to access the frontage road entrance ramp and Route 128 northbound. Since, under this configuration, volumes are not expected to exceed theoretical capacity, and present peak-period conditions last less than one hour, improvements would not necessarily be required under future volume levels. However, because the potential for problems does exist, the Town should monitor traffic conditions here closely.

4.1.2 Intersections Unaffected by the Build Alternatives

Several study-area intersections are not affected by the service and frontage road network alternatives:

Highland Avenue at Webster Street

Webster Street at Greendale Avenue

Needham Street at Oak Street and Christina Street

Needham Street at Winchester Street and Dedham Street

Winchester Street and Centre Street at Route 9 eastbound entrance exit ramp

Centre Street at Route 9 westbound ramps

The analysis of future year-1995 traffic operations was based on the same forecasts of future-year volumes used for section 4.1.1. For analysis purposes, the improvement recommendations made in the existing-conditions report were again assumed to be in place. The results of the level of service analysis are summarized in Table 4-2.

Highland Avenue at Webster Street

As of 1995, the Highland Avenue westbound approach may experience excessive left-turn delay problems due to the increased volume of westbound left turns and eastbound through and right-turning traffic. This would be the case even if improved channelization in the form of one exclusive left-turn lane or a shared through and right-turn lane were present. The addition of a second westbound shared (through and right-turn) lane would relieve the left-turn problem, although long delays would be expected.

Further analysis of this location would be appropriate at some future date when delay problems become apparent. Possible lane additions and changes to signal phasings and timings should be re-evaluated in detail at such a time.

Webster Street at Greendale Avenue

Operations at this intersection are expected to continue to be acceptable in the foreseeable future.

Needham Street at Oak Street and Christina Street

The operation of this intersection, which is located approximately at the midpoint of the study area, is critical to the corridor area. Under future-year traffic volumes, it is likely that two important capacity improvements will be required to maintain acceptable operations.

Christina Street must first be brought into alignment with Oak Street. This action is necessary to improve safety and eliminate left-turn/left-turn conflicts in the intersection.

Intersection/Configuration	Level of Service
Highland Avenue @ Webster Street	
o Exclusive left-turn lane on Highland, westbound	F
o Exclusive left-turn lane & two through lanes on Highland, westbound	E
Webster Street @ Greendale Avenue	
o Present configuration	A
Needham Street @ Oak Street & Christina Street	
o Signal installed, Christina Street aligned with Oak Street, exclusive left-turn lanes on Needham Street	F
o Signal installed, Christina Street aligned with Oak Street, exclusive left-turn lanes with two through lanes on Needham Street	C
Needham Street @ Winchester Street & Dedham Street	
o Improvements with two left-turn lanes on Needham Street	D
Winchester Street and Centre Street @ Route 9 Eastbound Entrance/Exit	
o Intersection geometric improvements	
Left turns from Centre Street	F
Left turns from ramp exit	F
Right turns from ramp exit	C
Centre Street @ Route 9 Westbound Ramps	
o Intersection geometric improvements	
Left turn from Centre Street, northbound	E
Left turns from westbound off-ramp	F
Right turn from westbound off-ramp	A
Right turn from Floral Street ramp	D

Highland Ave./Needham St.: Future Conditions	1995 LEVEL OF SERVICE ANALYSIS SUMMARY - INTERSECTIONS UNAFFECTED BY FRONTAGE ROAD AND SERVICE ROAD ALTERNATIVES	CTPS
Technical Report 56b July 1987		TABLE 4-2

Secondly, the volume of traffic on Needham Street is expected to increase to the point where one additional lane will be necessary in each direction to provide sufficient hourly capacity.

Winchester Street and Centre Street at Route 9 Eastbound Ramp and Centre Street at Route 9 Westbound Ramps

Even assuming that geometric improvements are made and exclusive left-turn lanes are installed for each of the possible left-turn movements, the potential remains high for excessive delay at each of these locations in future years.

The proximity of these intersections to each other necessitates that any treatments be closely coordinated between the two. This is particularly important if signals are to be installed.

The left-turn problems noted in Table 4-2, however, occur as a result of the heavy volume of through traffic on Winchester Street and Centre Street. The presence of too few acceptable gaps in this traffic for left-turning vehicles causes excessive delay. The introduction of signals at the Needham Street/Winchester Street/Dedham Street intersections should relieve this situation and cause traffic to move south to north (from Winchester Street to Centre Street) in a series of vehicle platoons. The gap times between vehicle platoons should be of sufficient duration to clear the left-turning traffic.

The long-term potential of the Needham Street/Winchester Street signal to introduce sufficient gaps to accommodate left turns at the Route 9 ramps is, however, uncertain. Installation of a coordinated pair of signals (which is not listed in Table 4-2) at each intersection would improve the level of service to D or better. The need for this additional improvement should be re-evaluated in detail over time as Needham Street/Winchester Street intersection improvements are established.

4.2 ROAD-SEGMENT NEEDS AND ALTERNATIVES

4.2.1 Highland Avenue Bridge

There are several issues for consideration regarding the long-term adequacy of the Highland Avenue Bridge, including: the need for additional capacity at the adjacent intersections, Highland Avenue/Second Avenue and Needham Street/Oak Street/Christina Street; the capacity of the bridge to service peak-hour volumes in future years; and the environmental and historical implications of altering the bridge structure.

The analysis of intersection capacity at the two intersections on either side of the Highland Avenue Bridge (discussed above in sections 4.1.1 and 4.2.2) indicates that additional

capacity will be necessary at each intersection by 1995 to maintain acceptable levels of service. Assuming that intersection capacity improvements can be accomplished, changes will also be required on the Highland Avenue Bridge to permit safe transition between the intersections and the bridge. This is particularly important with regard to the Oak Street/Christina Street intersection on Needham Street.

Oak Street is located approximately 280 feet from the Highland Avenue Bridge. Eastbound traffic approaching Oak Street from the bridge presently moves to either the left or the right from the bridge, depending on whether a left turn to Oak Street or a through movement/right turn is anticipated. Future-year traffic levels will require one exclusive left-turn lane, one through lane, and a shared through/right-turn lane for the approach to operate at level of service C.

When widening the intersection to permit maximum use of available right-of-way capacity, it will be necessary to provide two lanes on the bridge to allow traffic to continue to move to the left and right into appropriate approach lanes. Without two lanes in each direction on the bridge, the maximum queue length from the intersection that would still permit vehicles to maneuver into lane position (assuming average per-vehicle allowances of 40 feet) is seven vehicles. Beyond this queue length, traffic from the intersection would queue onto the bridge and block any further movements from the bridge into available approach-lane space at the intersection.

Future-year westbound traffic on Needham Street would also require one through and one shared through/right-turn lane for sufficient capacity at the Oak Street/Christina Street intersection to maintain level of service C operating conditions. Assuming this configuration, Needham Street west of Oak Street would have to narrow from 24 feet to one 15-foot lane within the 280 feet between Oak Street and the bridge, if the bridge were to remain a two-lane section. To examine the merge capacity of this section, an application of gap theory as described in Chapter 10 of the 1985 Highway Capacity Manual (Transportation Research Board Special Report 209) was used. The results of the analysis are presented below and in Table 4-3.

Assuming a four-second critical gap time for the low-volume lane merge yields an hourly merge capacity of 639 passenger-car equivalents. The low-volume lane (through) movement on Needham Street westbound is forecast at 670 passenger-car equivalents during the PM peak hour. This exceeds the merge section capacity due to the high density of median lane volume, which limits the number of acceptable gaps available to the merging traffic. A second lane will, therefore, be required to service peak volumes.

TABLE 4-3

Analysis of Westbound Highland Avenue Bridge Merge Capacity

$$C = 6130.85/G * \exp(-.00021 * G * V)^{1}$$

where:

C = capacity
G = critical gap in seconds
V = hourly volume

For Needham Street westbound

$$C = 6130.85/4.0 * (-.00021 * 4.0 * 1042)$$
$$= 639 \text{ VPH}$$

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[1]From 1985 Highway Capacity Manual (Transportation Research Board Special Report 209), Figure 10-3, p. 10-7.

The analysis of peak-hour traffic conditions from Second Avenue indicates that acceptable levels of service (C or better) are possible if signal timing is optimal and the westbound Highland Avenue approach to Second Avenue is revised to accommodate two through lanes and one exclusive left-turn lane. In addition, the Second Avenue approach should be restriped as a double left-turn lane and right-turn bay. Neither of these actions changes the Highland Avenue eastbound vehicle capacity, which, therefore, does not increase at Second Avenue and is not further justification for adding lane capacity to the bridge.

Nevertheless, due to the future-year demand levels from the Needham Street side, particularly the Needham Street/Oak Street/Christina Street intersection, consideration should be given to continuance of the four-lane bridge section west of the bridge on Highland Avenue to Second Avenue. Extension of the four-lane section from Second Avenue across the bridge would provide four travel lanes on all corridor sections where future-year all-day traffic demands are likely to exceed 35,000 vehicles.

Assuming that a four-lane bridge section is in place at some future date, it will be important to maintain the four-lane cross-section to the intersections on either end of the bridge for the purpose of continuity alone. However, future-year demands across the bridge and along Highland Avenue between the bridge and Second Avenue are likely to exceed possible capacity

by 1995. Table 4-4 presents an estimate of the possible capacity (service volume capacity at level of service E) of the bridge segment and an estimate of future-year demand volumes. Possible capacity is estimated at 1,804 vehicles per hour per lane for the bridge. Assuming signals are installed and optimally timed, projected peak-hour volumes in the direction of the bridge can be converted into platoon volumes. Conversion of hourly volumes to platoon volumes is necessary to correct for the fact that, under signal control, directional volumes are not distributed evenly over the course of an hour, but are released in a series of platoons.

With properly operating signals, 100 percent of the hourly demand is serviced within some fraction of the hour. The effective hourly demand is, therefore, higher than actual vehicle volume. To determine the adequacy of a road segment, hourly volumes must be adjusted to reflect the hourly service volume produced during different signal phases. The adjusted volume reflects the effect of vehicle platoons as if platoons were distributed evenly during the peak hour. This volume is equivalent, for comparison purposes, to the hourly road segment estimate of capacity.

These volumes are shown in the last section of Table 4-4. Comparing these platoon volumes to the hourly, per-lane capacity of the bridge (1,804), the eastbound Highland Avenue traffic platoon (2,363) and the westbound Oak Street and Christina Street platoon (1,980) are likely to cause traffic congestion at the bridge, as anticipated flows periodically exceed available capacity. The extent of the delay and the queue lengths will be dependent on the amount of time between queues. Efficient signal operation, which minimizes the time between vehicle platoons, would limit the ability of vehicles to clear the bridge before other platoons arrive. In addition, the fact that capacity problems will exist in both directions limits the kinds of possible alternatives which can be used to improve conditions.

There are essentially three options for providing sufficient lane capacity across the river.

1. Reconstruct the bridge and widen to four lanes.

2. Remove sidewalks, restripe the bridge deck as four lanes, and either construct a separate, pedestrian river crossing or cantilever a pedestrian crossing from the existing bridge structure.

3. Designate the existing bridge as one-way and construct a second two-lane, one-way facility parallel to the present one.

Capacity

Directional service volume at LOS E (SVe)	=	2,000 VPH
Number of lanes	=	1 lane
Lane width	=	14.5 feet
Lane width reduction factor (LWR)	=	1.0
Distance from lane edge to obstruction	=	2.5 feet
Lateral clearance reduction factor (LCR)	=	.93
PM truck percentage (peak direction)	=	3.94%
Truck percentage adjustment factor (TRF)	=	.97

Adjusted SVe = SVe * LWR * LCR x TRF

Highland Avenue Bridge adjusted SVe =
2000 * 1.0 * .93 * .97 = 1,804 VPH

Demand

Projected 1995 PM peak hour passenger-car equivalents (PCE)

Highland Avenue eastbound through movement from Second Avenue	=	1,300
Right-turn volume from Second Avenue to Highland Avenue eastbound	=	172
Right turn from Oak Street/Left turn from Christina Street to Highland Avenue westbound	=	269
Needham Street westbound volume from Oak Street	=	1,116

Conversion to Platoons on the Basis of Green Time Percentage per Hour

Through volume, Highland Avenue eastbound 1300 VPH - .55 G/C* per hour	=	2,363
Right-turn volume, Second Avenue 172 VPH - .44 G/C per hour	=	391
Right & left-turn volume, Oak Street and Christina Street 297 VPH - .15 G/C per hour	=	1,980
Through volume, Needham Street westbound 1271 VPH - .85 G/C per hour	=	1,495

*G/C is green time per traffic-signal cycle.

Highland Ave./Needham St.: Future Conditions Technical Report 56b July 1987	HIGHLAND AVENUE BRIDGE CAPACITY AND DEMAND ANALYSIS	CTPS TABLE 4-4

Environmental and historical issues must be considered in the selection of bridge improvement actions. The Highland Avenue Bridge, identified by the Massachusetts Historical Commission as site N-4-2, was built of stone in 1875. An elliptical, three-span design, the bridge may not have been pointed when originally built, although it is at present.

The Charles River is the corridor's primary natural feature. Immediately north of the Elliot Street corridor boundary, the Charles River passes through Hemlock Gorge. The gorge is in an area of natural waterfalls where the river has cut through a stratum of puddingstone. South of the Highland Avenue Bridge, the river is bordered by the MDC's Charles River Reservation. The South Meadow Brook, which also courses through the corridor from its source in Brookline, joins the Charles River immediately south of the bridge.

Clearly, the bridge and the surrounding area are historically and environmentally sensitive. Actions taken to improve the capacity of the river crossing must be in compliance with federal and state environmental statutes. For major improvement actions such as constructing an additional bridge, federal regulations require preparation of an Environmental Impact Statement (EIS). State regulations require the filing of an Environmental Notification Form (ENF) and, if the action is deemed "major," preparation of an Environmental Impact Report (EIR). Should the determination be made that a proposed work activity does not contain potentially significant environmental impacts, the project may proceed within the guidelines set forth by the state and jurisdictional municipalities. Any potential impact to the Charles River from efforts to improve the bridge would also be subject to the Massachusetts Wetlands Protection Act, which requires municipal approval through the local conservation commission of any alteration of wetlands.

Among the capacity-improvement options outlined above, the second option (remove sidewalks, restripe bridge deck as a four-lane section, and relocate sidewalks) would have the fewest environmental effects.

4.2.2 Highland Avenue

Highland Avenue from Webster Street to Hunting Road and Gould Street

Future-year volume increases on Highland Avenue and Webster Street will require improvements at the Highland Avenue/Webster Street intersection if acceptable service levels are to be maintained. An approach to Webster Street with two through lanes and one exclusive left-turn lane would provide necessary westbound capacity on Highland Avenue. To maintain continuity on Highland Avenue between the Gould Street/Hunting Road intersection and the Webster Street intersection, consideration might be given to restriping the surface as a four-lane section.

Highland Avenue from Hunting Road and Gould Street to Route 128 Ramps

The potential for operational problems on this road segment is expected to increase with time. Demands for access to Gould Street and Hunting Road are expected to grow as area redevelopment continues. As demands increase in and around the Gould Street industrial area, movements to and from Gould Street will require close monitoring. Trips from Route 128 will increase AM right turns from Highland Avenue to Gould Street. Return (PM) trips will increase the volume of the already critical left-turn movement from Gould Street to Highland Avenue.

In addition, movements from Route 128 southbound onto Highland Avenue which turn left onto Hunting Road must weave across two lanes to reach the left-turn lane at Hunting. Although no field counts of the weave traffic have been taken, the weave movement was observed on several occasions. The weave section is approximately 225 feet from ramp gore to left turn lane entrance. A high percentage of the traffic exiting the Route 128 southbound ramp weaves across Highland Avenue to turn left on Hunting Avenue during the AM peak period. This path is primarily used to reach the Wells Avenue at Route 128 Office Park from the north.

With the exception of the fact that through-trip traffic is channeled into the residential section of Hunting Road, return trip (PM) traffic problems influenced by this traffic are less severe. On returning to the Highland Avenue/Hunting Road/Gould Street intersection in the afternoon, this traffic moves as a right turn from Hunting Road in the direction of the Route 128 northbound ramps during the same signal phase as that in which the left-turn movement from Gould Street to Highland Avenue westbound is made.

Analysis indicates that these combined (PM) movements may be problematic in future years. However, the double-lane Highland Avenue westbound exit from the intersection should be sufficient to service these additional demands, as both moves can be made concurrently without conflict. Nevertheless, since analysis does indicate a potential for operational problems, the section should be periodically monitored. Further evaluation of the segment and future traffic operations should also be considered in conjunction with planned Route 128 improvements.

Highland Avenue from Westside Route 128 Ramps to Eastside Route 128 Ramps

No safety or capacity problems are anticipated and no improvement actions appear warranted.

Highland Avenue from Route 128 Ramps to Second Avenue

This section of Highland Avenue is the most congested and hazardous section within the study area. Future-year volumes will substantially exceed existing levels regardless of which frontage road/service road alternative is constructed. While each of these proposals does benefit traffic operations on Highland Avenue, none of them brings about acceptable vehicle operations.

Traffic problems on this segment, existing and anticipated, are chiefly related to four factors:

1. High volumes exit the New England Industrial Center at First Avenue to access Highland Avenue westbound and Route 128. This traffic maneuvers around the median which blocks the left turn from First Avenue. Several different moves are executed by the motorists, causing confusion and conflicts in the Highland Avenue traffic stream.

   To eliminate this problem while maintaining maximum accessibility to local land use, several steps are required, including the following:

   - Construction of the frontage road with direct access to Route 128 northbound.

   - Construction of a one-way service road from First Avenue to Second Avenue that would improve access to Second Avenue from the northwest quadrant of the industrial center.

   - Prohibition of traffic movements from First Avenue to Highland Avenue.

   Another option that has been suggested for implementation in conjunction with the frontage road, but which is considered infeasible, is shortening the median on Highland Avenue to a point west of First Avenue and improving the intersection with signals. Although construction of a frontage road interconnecting with the Route 128 56E ramps may provide sufficient storage for traffic that might otherwise unsafely queue onto Route 128 northbound, a similar storage solution would be essential (in the case of this median-shortening option) for the southbound (westside) ramps to prevent AM peak period queues from extending from eastbound Highland Avenue onto southbound Route 128. Although the absence of Exit 56E traffic on Highland Avenue eastbound under a frontage road scenario would provide some improvement and queue-length reduction, future-year volumes would

compensate for the decline caused by this diversion. Equally important is the fact that location of a signal any closer to Route 128 (west of Second Avenue) would eliminate storage space, exacerbating the problems.

2. Left turns from Highland Avenue onto Wexford and Charles streets create further problems. Although the volume of left turns is low at each location, the interruption of the high volume of Highland Avenue traffic to complete the moves--combined with interruptions by left turns from Wexford and Charles onto Highland--significantly disrupts traffic flow on this section and interferes with the efficient operation of the Second Avenue signal.

   Analysis has shown that under future-year traffic conditions, the Highland Avenue through-traffic volume levels will use all available capacity and block all possible left-turn movements into Wexford Street and Charles Street. Unless actions which formally prohibit left turns into either street from Highland Avenue are implemented, these left turns have the potential to severely disrupt and reduce the effectiveness of other capacity improvements made at other intersections or on segments east of the site. To eliminate these left turns, while continuing to provide access, the following options can be considered:

   - Construct a one-way service road from First Avenue to Second Avenue. Left-turning, eastbound Highland Avenue traffic could be channeled onto the service road from First Avenue. This traffic would exit the industrial center on Second Avenue and turn left at the Highland Avenue/Second Avenue signal to reach Charles Street and Wexford Street (see Figure 3-2).

   - Widen and restripe Highland Avenue as a five-lane section with a continuous median left-turn lane to the southside of Highland Avenue. The left-turn lane would serve to prohibit left turns from Highland to the north (into Wexford Street and Charles Street) and would remove left turns to the southside of Highland Avenue from the westbound stream until acceptable gaps became available in the eastbound stream.

   - Signing of a left-turn prohibition and alternate access pattern.

   Other options which have been suggested but are considered infeasible include:

   - Widening and restriping the segment as a five-lane section with a continuous, two-way, left-turn, median

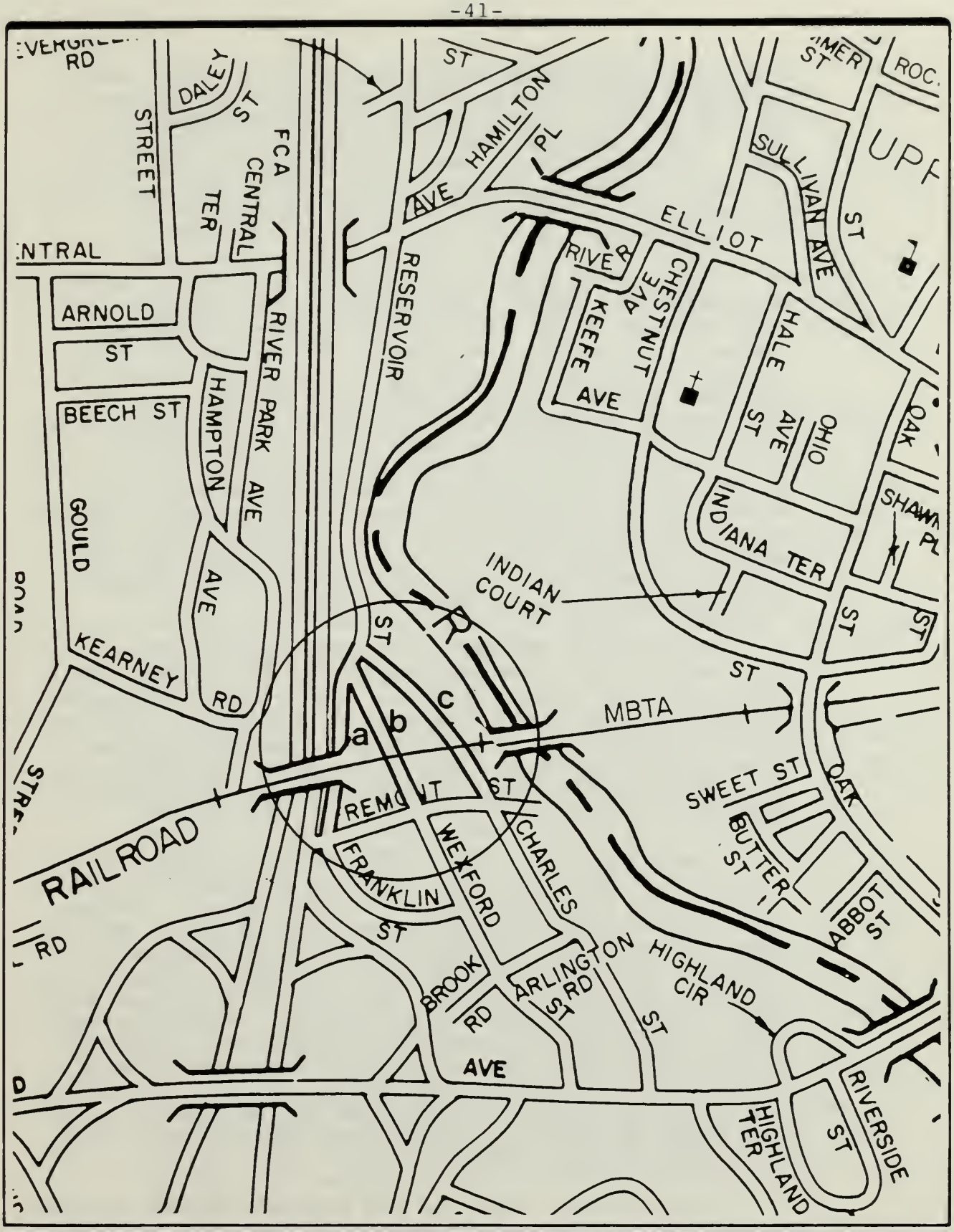
lane. This option would permit left turns to be made from Highland Avenue to Wexford Street and Charles Street. As discussed earlier, the excessive delay associated with left turns from Highland Avenue to Wexford Street and Charles Street in future years would force left turns to be made inappropriately as partial crossings (i.e., one lane at a time) and substantially reduce the hourly capacity of the Highland Avenue westbound section. This would be highly disruptive to all upstream traffic operations on Highland Avenue westbound.

- Widening and restriping the segment as a five-lane section with a continuous left-turn median lane to the northside of Highland Avenue. This option shares the same shortcomings as the one described immediately above.

3. Left turns from Wexford Street and Charles Street onto Highland Avenue eastbound are also problematic. As access from Needham to the Wexford Street/Charles Street area is restricted by difficulties making left turns from Highland Avenue to Wexford and Charles, access to Newton is similarly restricted by difficulties in making left turns from Wexford and Charles onto Highland Avenue. Under future traffic volumes, through movements on Highland Avenue will block all left-turn movements from either Wexford Street or Charles Street during peak periods. Left turns forcibly made from these streets will also be made as partial crossings. This process will have substantially disruptive effects on the Highland Avenue/Second Avenue intersection and on all traffic approaching the intersection from the east.

   One possible solution to this problem is to prohibit left-turn movements into and from Wexford and Charles streets with appropriate regulatory signing. This option does constrain land-use access somewhat, in that traffic into Wexford Street and Charles Street from Needham and Route 128 would require an alternate means of access such as the service road discussed above. Similarly, exiting volumes from Wexford and Charles streets to Newton destinations would be required to turn right and use either Route 128 to Route 9 to reach Newton or to reverse direction at the Route 128 ramps or the Highland Avenue/Gould Street/Hunting Road in a U-turn.

4. To limit the need for this circuitous diversion of traffic and to provide equivalent levels of land-use access, a connection to Reservoir Street from Charles Street, Wexford Street, or Franklin Street may be possible. Reservoir Street connection alternatives are shown in Figure 4-2. Reservoir Street is parallel to Route 128,



Highland Ave./Needham St.: Future Conditions	ALTERNATIVE ALIGNMENTS OF WEXFORD/CHARLES STREET EXTENSION TO RESERVOIR STREET	CTPS
Technical Report 56b July 1987		FIGURE 4-2

extending south from Central Avenue to a point immediately north of the railroad right-of-way opposite Charles Street. Central Avenue crosses Route 128 to the west, and intersects with Gould Street and, further west, with Webster Street. To the east, the Central Street right-of-way crosses into Newton as Elliot Street. Elliot Street to the east intersects with Oak Street and with Route 9.

Restricting left turns without creating a Reservoir Street outlet, essentially limiting the movements to and from Wexford Street and Charles Street at Highland Avenue to right turns is simpler to implement. This concept is frequently applied in situations where new driveway access to a site such as a shopping center would cause unacceptable deterioration in levels of service. The benefit to traffic flow is that conflicts are minimized (right-turn conflicts are the least disruptive to through traffic) and are restricted to the flow in one direction. The prime disadvantage is that land-use access is constrained, as access routes often become more circuitous. This can be a particularly critical concern on sections, such as Highland Avenue, where unlimited access is already available.

As has been alluded to briefly above, efforts have been made to maintain available levels of access while addressing the traffic problems which are anticipated. The decision of whether to advance the concept of right turns only into and from Wexford Street and Charles Street will depend on political support and the feasibility (cost and engineering) of other less constraining options.

Another possibility is the combination of the option of right turns only into and from Wexford and Charles with the extension of Wexford Street, Charles Street or Franklin Street to Reservoir Street. The creation of a link between Charles Street and Wexford Street to Reservoir Street north of the railroad tracks would restore the reduction in accessibility that would result from the left-turn prohibition. Traffic originating in Needham would be able to reach the Wexford/Charles area on Central Avenue and Reservoir Street rather than from Highland Avenue directly. Similarly, traffic exiting the area destined for Newton and points east would be able to use Reservoir Street to Central Avenue and Elliot Street.

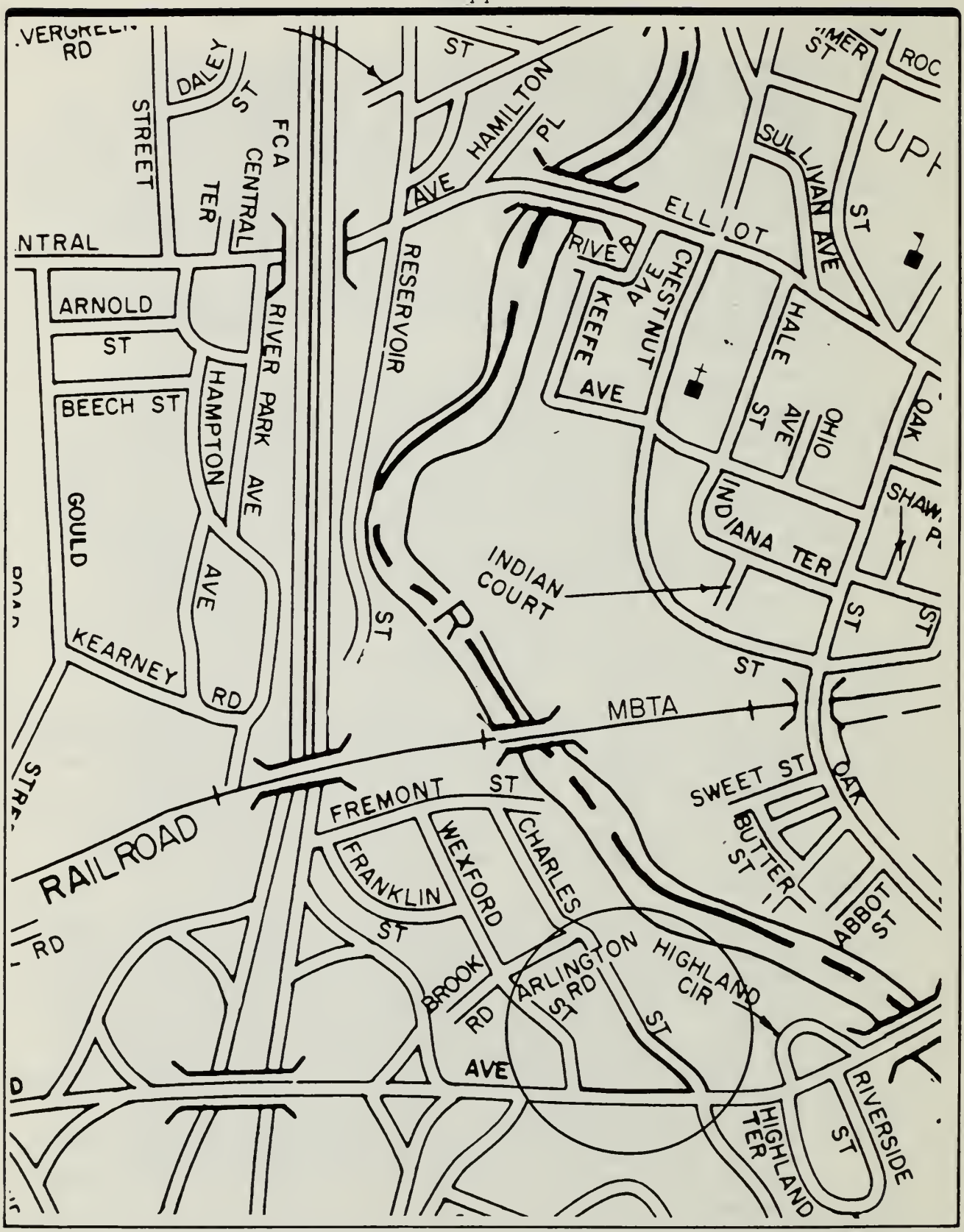
The long-term needs of the Highland Avenue section between Second Avenue and Wexford Street may require that, if no left-turn restrictions were implemented, the functional equivalent of a Resevoir Street connection be

made anyway, to relieve the difficulty encountered in executing left turns to and from Highland Avenue generated by the Wexford Street and Charles Street land uses. As traffic volumes in the Highland Avenue corridor continue to increase in future years, the difficulty of executing these left-turn movements will increase and a decline in accessibility will, in effect, occur. More importantly, the volume of left turns will increase, causing a commensurate increase in pressure on the lead vehicle in the queue to initiate movement. This condition can be expected to cause a further reduction in area safety. Land access will be of secondary concern at that point.

There are several considerations affecting the long-term viability of the Resevoir Street connection alternative. In order to complete the connection, it will be necessary to find a suitable means of passing through the railroad embankment. At present, a direct passage from the end of Wexford Street, Charles Street, or Franklin Street is blocked by buildings on Fremont Street. Demolition would be required in conjunction with the construction if one of these options were chosen. An alternative to direct alignment is to construct a new alignment for which a passage under the railroad tracks could be made in conjunction with the Route 128 add-a-lane project.

Finally, a means of maintaining similar levels of land-use accessibility that would also introduce a safer means of vehicle control is to directly align Charles Street and Second Avenue (see Figure 4-3). To accomplish this, either Charles Street or Second Avenue would be re-aligned. The objective is to bring all conflicting movements under the control of a single signal.

The difficult aspect of this alternative is right-of-way acquisition and preparation. All quadrants of the Highland Avenue intersection with Second Avenue and with Charles Street are occupied with commercial developments. Right-of-way acquisition for alignment could involve swapping the present right-of-way of Second Avenue or Charles Street for land required for the new alignment. Acquisition costs would thus be pared to the cost of the buildings. The Town of Needham could request MDPW assistance in the determination of right-of-way requirements and the identification of the lowest-cost option prior to initiating the acquisition process.



Highland Ave./Needham St.: Future Conditions	ALIGNMENT OF CHARLES STREET AND SECOND AVENUE	CTPS
Technical Report 56b July 1987		FIGURE 4-3

Highland Avenue from Second Avenue to the Highland Avenue Bridge

The need for additional capacity on the Highland Avenue Bridge extends to the Highland Avenue road segment between the bridge and Second Avenue, as discussed in section 4.2.1. The 1995 peak-period traffic volumes are expected to exceed the capacity of the one-lane westbound segment from the bridge (1,980 vehicles per hour demand vs. 1,804 vph capacity) and of the eastbound merge segment from Second Avenue (2,360 vph vs. 1,940). In addition, if a lane is added in each direction on the bridge (which appears to be the only reasonable solution to the capacity problem which will exist in the future), extending the four-lane section along the segment to Second Avenue would ensure that midblock bottlenecks would be avoided.

Confirmation is needed regarding the availability of a 60-foot right-of-way for sidewalks and the additional lanes along this segment. The segment length between the Highland Avenue Bridge and Second Avenue is approximately 750 feet. Extension of the four-lane section for this distance would eliminate the eastbound merge section and reduce the adverse effects of left turns on through traffic movements. Westbound, the addition of a lane would permit traffic to move from the bridge to the Second Avenue intersection in two lanes, both of which could be used by through traffic for queuing, because a third, left-turn storage lane would also be added at the intersection. Lane switching would be minimized and queues would be reduced by the availability of additional storage space.

The other option considered for this segment was the addition of a continuous left-turn median lane to the four-lane section. Although it was clear from the analysis that four through lanes would be required to serve future demands, the anticipated land-use changes are not expected to significantly alter the proportional demand for left turns. Therefore, as was concluded in the evaluation of existing conditions, left-turn demands along this segment will be insufficient to warrant a left-turn median lane.

4.2.3 Needham Street

Needham Street from Oak Street to Winchester Street

The probability of continued commercial development in the Newton Industrial Center, with a commensurate decline in the presence of manufacturing activities, will cause a continuous increase in the demand for roadside access along Needham Street through the forecast period. As traffic volumes increase, increases in the number of midblock turning movements are expected. Under present conditions, midblock accidents occur here at a rate far above the statewide average for similar facilities.

Although the presence of a three-lane section with a continuous, two-way, left-turn median lane will provide control and safer vehicle operations over the short-term, as traffic volumes grow the utility of the left-turn median lane will decline. As queues in the median lane increase, conflicts will arise between vehicles already queued and vehicles attempting to enter the median lane to make left turns. Vehicles attempting to enter the left-turn lane will be forced to queue on the inside through lane until median queues dissipate sufficiently to allow entrance. The presence of stopped vehicles in the through traffic lane under these conditions can, in the worst case, result in localized gridlocking. As motorists already in the median lane or those attempting to enter it realize that the intended left-turn cannot be executed, the attempt will be abandoned. Instead, use of sidestreets and the median lane (at other locations) will increase, and an increase in midblock U-turns will result.

On Needham Street, 1995 traffic levels are expected to exceed 1984 levels by 30 to 35 percent; average daily traffic volume increases will be in the range of 9,000 vehicles. Assuming that the peak-hour percentage of average daily traffic in 1995 is similar to the current percentage, Needham Street peak-hour traffic should increase by 250 to 400 vehicles in each direction. Peak directional flows would, under these conditions, be between 1,100 and 1,500 vehicles per hour. These volumes will require additional lanes to provide acceptable levels of service.

For urban arterials such as Needham Street, hourly capacity is a function of intersection capacity. Typically, ideal lane capacity is 1,800 vehicles per hour. Assuming 60 percent green time on Needham Street and a 70 percent adjustment for level of service C conditions, average lane capacity is between 750 and 800 vehicles per lane per hour excluding adjustments for vehicle mix, lateral clearance and driveways. Clearly, four through lanes will be necessary on Needham Street to adequately meet future-year peak-hour demands. And, for the reasons cited above, the utility of a continuous two-way left-turn lane is uncertain under these volumes, but would be expected to limit the efficiency of the four-lane section.

Left-turn demands on Needham Street are not, however, expected to decline unless driveway openings and curb-cuts are reduced along the corridor. To demonstrate the effect of curb-cuts and left-turn demands on the performance of Needham Street road segments, use was made of the arterial section analysis procedures in the 1985 Highway Capacity Manual (Transportation Research Board Special Report 209).

Turning movements were sampled at a number of representative driveways along Needham Street. The delay caused to through movements at each driveway was determined on the basis of the sample data. Estimated delay to through traffic ranged from 3.6 to 8.2 seconds per vehicle, with the average falling between 3.9

and 4.3 seconds. By assigning an estimate of delay to each driveway and intersection, Needham Street sections were evaluated for average speed and level of service. The results of the analysis are summarized in Table 4-5 below.

Table 4-5

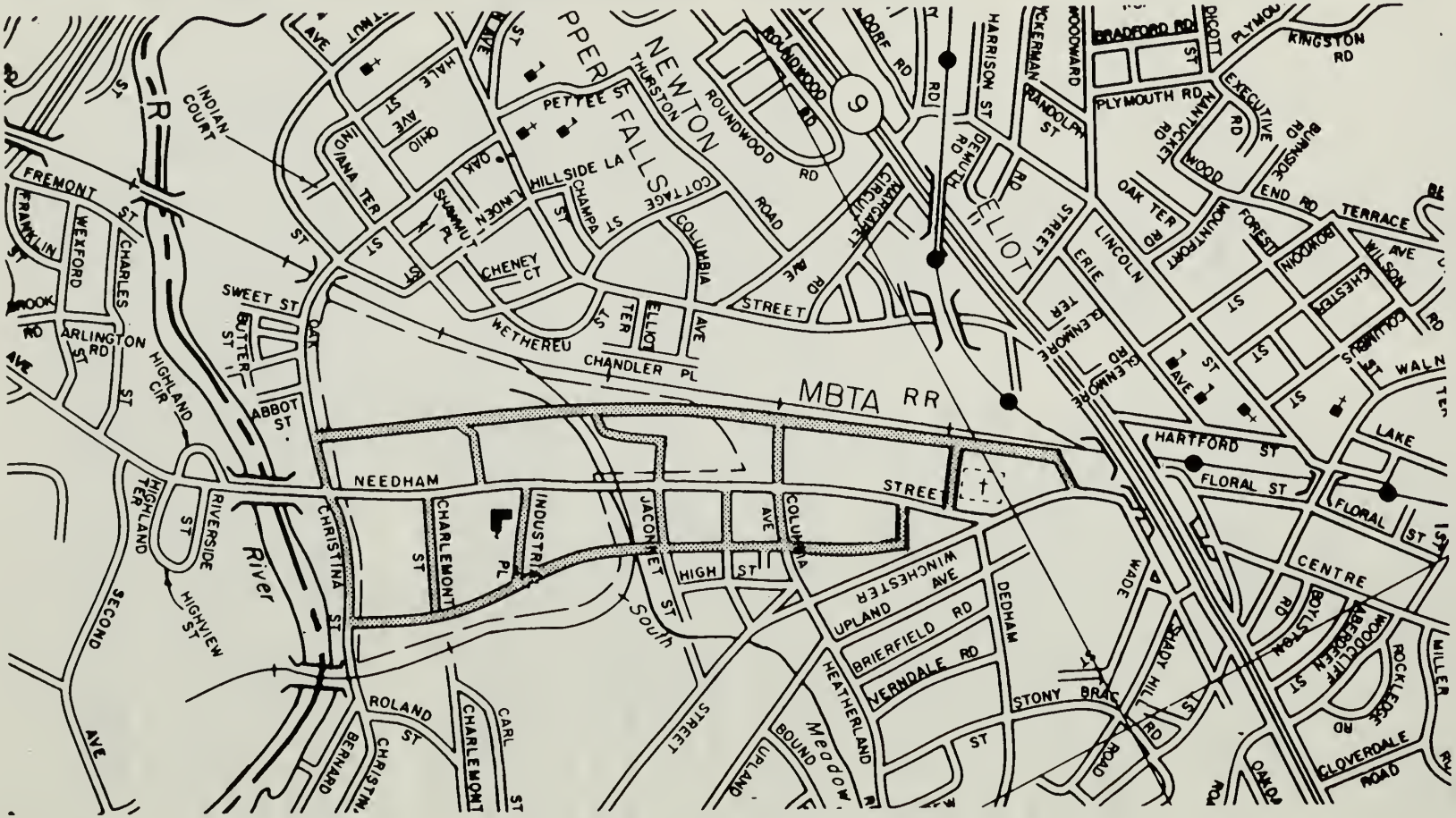
Level of Service
Evaluation of Needham Street Segments, 4pm-5pm, 1986

Section	Average Speed	Level of Service
Winchester Street to Columbia Rd. WB	9.2 mph	D
Columbia Rd. to railroad tracks WB	10.4 mph	D
Railroad tracks to Christina Street WB	8.9 mph	E
Christina Street to railroad tracks EB	8.9 mph	E
Railroad tracks to Columbia Rd. EB	10.2 mph	D
Columbia Rd. to Winchester Street EB	6.9 mph	F

The results indicate that through-traffic is delayed most on approaching the Needham Street intersections with Oak Street, Winchester Street, and Marshall's Plaza. More important, however, is the fact that, although individual delays of only three or four seconds at individual driveways are compatible with a level of service A or B rating, when these small delays occur in series along an arterial segment, the overall level of service and speed decline considerably.

Because future-year volumes and left-turn demands on Needham Street are expected to increase on the order of 35 percent between the present and 1995, proportionate effects on speed and level of service can be expected unless some action to limit the effect of driveways on capacity is taken.

One feasible alternative is the creation of an internal circulation scheme that would provide access to each of the Needham Street properties from a new facility set approximately 200 feet back from Needham Street. An internal circulation scheme is shown in Figure 4-4. With access provided from behind the businesses on Needham Street, driveways can be closed; access to the circulation facilities from Needham Street would be limited to signal-controlled intersections. Although the evaluation of the plan as part of this study was constrained by limitations on the availability of data, and time limitations prevented an evaluation of the potential for trip diversion, a partial evaluation was completed.



Schematic Location of Circulation Facility

Highland Avenue/Needham Street Traffic Study: Future Conditions	NEEDHAM STREET INTERNAL CIRCULATION PLAN	CTPS
Technical Report 56b July 1987		FIGURE 4-4

Two Needham Street segments were re-evaluated assuming that all curb-cuts were closed and that delay to through traffic at the end-point intersection (Winchester Street and Dedham Street or Oak Street and Christina Street) was increased by 50 percent to account for the additional traffic volume diverted to the intersection by the curb-cut closures. Under these conditions, on the segment between Columbia Road and Winchester Street, eastbound, average operating speed improved from 6.9 mph to 9.2 mph and level of service from F to D. Similar improvements were found between the railroad tracks and Oak Street, where average westbound operating speed would be expected to improve from 8.9 mph to 10 mph, changing the segment's level of service from E to D. In a more detailed analysis, which would include the effects of the diversion of some percentage of the local traffic presently on Needham Street to the circulation facilities, further improvement in Needham Street operations would be anticipated.

4.2.4 Winchester Street

The segment of Winchester Street from Dedham Street to Route 9 is expected to experience increases in travel demand of approximately 34 percent between 1984 and 1995. Peak-hour traffic volumes are expected to be roughly equivalent to those on Needham Street, necessitating four through travel lanes to adequately serve peak-period traffic.

Land-use development on this segment of Winchester Street is predominantly on the eastern side of the street. Nevertheless, field visits have indicated that left turns are not of sufficient volume to require midblock treatment such as exclusive turn lanes. Furthermore, as indicated in Figure 4-4, access to the northside of the internal circulation facility will be from Winchester Street immediately south of Route 9, potentially reducing some portion of the projected (southbound) Winchester Street traffic.

With respect to the intersections of Winchester Street with the Route 9 ramps, as discussed in preceding sections, analysis indicates the potential for severe delay problems by 1995. Although improvement actions planned to correct existing problems at the Needham Street/Winchester Street/Dedham Street intersection are expected to greatly improve the present-day operations of the Winchester Street/Route 9 ramp intersections, signal control may be required in the future. Satisfactory levels of service are possible with signal installation; however, detailed re-evaluation should be considered five to ten years hence.

5 RECOMMENDATIONS

In evaluating the capability of the Consensus Plan actions and CTPS-developed actions to meet the long-term needs of the Highland Avenue/Needham Street corridor, traffic operations were examined in detail throughout the study area. Problems involving either vehicle movement or safety were identified. The various alternatives were analyzed in order to determine the optimal mix of improvements.

The recommended set of measures for long-term improvement of travel conditions in the corridor is presented in Table 5-1 by location, with the corresponding Consensus Plan actions shown for comparison.

Location/Element	Consensus Plan Action	Recommended Long-Term Action
1st Avenue Intersection	o Open median o Install traffic signal o Allow all movements inbound & outbound	o Allow only inbound (EB-to-SB) right turn o Median remains closed o No traffic signal installed o 1-way SB traffic only (Highland Ave to HoJo driveway)
Jug-handle/ Service Road (Jud-handle Effect at 2nd Avenue)	Not an element	o If right-of-way can be identified between "A" Street and Highland Ave: construct 1-way (W to E) roadway between 1st & 2nd aves. If "A" Street proves to be only feasible connection between 1st & 2nd aves., use existing "A" Street as connection
Highland Avenue (Route 128 to 2nd Avenue)	o 5-lane roadway with 2 EB, 2 WB, 1 Continuous 2-way left-turn lane	o 5-lane roadway with 2 EB, 2 WB, 1 Continuous 1-way (WB) left-turn lane for accessing land uses on south side of Highland btwn 2nd Ave & median o Median remains o Continuous left-turn lane informally used as "safety island" for WB south-side left-turners
2nd Avenue Intersection	o 5-lane roadway with 2 EB, 2 WB, 1 Continuous 2-way left-turn lane	o West approach: 2 lanes o East approach: 3 lanes with 2 through and 1 exclusive left-turn lane to 2nd Ave SB o South approach: 3 lanes, with 2 left-turn lanes to Highland Ave WB & 1 lane to Highland Ave EB o Jug-handle/Service Road incorporated o Also see Charles Street intersection
Highland Avenue Bridge	o 2 EB, 2 WB lanes	o 2 EB, 2 WB lanes on existing bridge piers, with sidewalks cantilevered to the outside

Location/Element	Consensus Plan Action	Recommended Long-Term Action
Charles Street Intersection	None	o Align with 2nd Ave o Split approach into 2 lanes with 1 shared lane for through & right-turn movements & 1 exclusive left-turn lane o Operate under 2nd Ave signal control o Left-turn prohibition from Highland EB to Charles
Wexford Street Intersection	None	o Left-turn prohibition from Highland EB to Wexford o Right-turn only operation (both in and out)
Franklin Street/ Reservoir Street	None	o Relocate eastern abutment of railroad bridge spanning Rte 128 EB to provide sufficient R-O-W to allow Franklin Street (extended) to connect with Reservoir Street in two-lane, two-way operation
Median U-Turns at Wexford to travel WB toward Rte 128	o Median removed at 1st Ave, thus removing U-turn necessity but springing loose left turns	o Prohibition of left turns from Highland EB, WITH ENFORCEMENT (Provision of U-turn facility for WB movement via jug-handle)
3rd Avenue Intersection	Not included in geographic area of Consensus Plan	o 1-way operation of 3rd Ave SB* (outbound from NEIC) o Traffic-light-controlled SB 3rd Ave approach split into 1 exclusive right-turn lane & 1 exclusive left-turn lane o EB & WB approaches on Kendrick split to 2 through lanes each

*Operation of 3rd and 4th avenues as one-way would be for only the first 500 feet north of Kendrick Street, i.e., as "gateway" points. Both 3rd and 4th would operate as two-way streets within the NEIC for internal NEIC-circulation purposes.

Location/Element	Consensus Plan Action	Recommended Long-Term Action
4th Avenue Intersection	Not included in geographic area of Consensus Plan	o 1-way operation of 4th Avenue NB* (inbound to NEIC) o 4th Ave 2 lanes NB from intersection o Eastern approach on Kendrick split into 1 exclusive right-turn lane & 1 through lane o Western approach on Kendrick split into 1 exclusive left-turn lane & 1 through lane
"B" Street Extension	Not included in geographic area of Consensus Plan	o Connection of 3rd Ave & 4th Ave via extension of B St as 2-way roadway to ease circulation of traffic with separation of inbound & outbound "gateways" on southern side of NEIC
Oak/Christina Intersection	o Signalize o West approach: 2 through lanes (1 shared with right turns); 1 exclusive left-turn lane (continuation of Continuous 2-way Left-Turn lane) o East approach: 2 through lanes with one shared with right turns; 1 exclusive left-turn lane (continuation of Continuous 2-way Left-Turn lane)	o Align Christina with Oak, maintaining existing Oak alignment o Signalize o West approach: 1 lane with shared right turn & through; 1 through; 1 exclusive left-turn lane o East approach: 1 lane with shared right-turn & through movements; 1 through; 1 exclusive left-turn lane o North approach: 1 exclusive right-turn lane; 1 lane with shared left-turn & through movements o South approach: 1 lane shared by all movements
Needham Street (Oak/Christina to Winchester)	o 5-lane roadway with 2 EB, 2 WB, 1 Continuous 2-way left-turn lane	o 4-lane roadway with 2 EB, 2 WB lanes between intersections o Construct an internal roadway set back within 200 ft from Needham St to serve local access to Needham St businesses

*Operation of 3rd and 4th avenues as one-way would be for only the first 500 feet north of Kendrick Street, i.e., as "gateway" points. Both 3rd and 4th would operate as two-way streets within the NEIC for internal NEIC-circulation purposes.

Location/Element	Consensus Plan Action	Recommended Long-Term Action
Needham Street (Oak/Christina to Winchester), cont.		o Close all driveway curb-cuts on Needham St excepting one Honeywell drive and McDonalds/N.E. Concrete Pipe. o Formalize remaining side street intersections on Needham St
Dedham/ Winchester Intersection	o Signalize & make geometric improvements	o Signalize & make geometric improvements
Winchester Street/Route 9 EB Ramp Intersection	o Signalize	o Flashing beacon with geometric improvements o Monitor; possible future signalization, if operationally required
Center Street Route 9 WB Ramp Intersection	o Signalize	o One-way operation with flashing beacon & geometric improvements o Monitor; possible future signalization, if operationally required
Floral Street	Not included in geographic area of Consensus Plan	o Establish 2-way operation o Restrict access to ramp to right turn only o No physical barrier
Route 9 WB Ramp Apartment Driveway	Not included in geographic area of Consensus Plan	o Prevent access to Rte 9 ramp o Provide access to Center St
Frontage Road	o Construct a NB frontage road parallel to Rte 128 along western border of NEIC o Access from slip ramps on NB Rte 128 and WB Kendrick St o Egress onto "A" St in the NEIC, Rte 128 NB, Highland Ave EB o Serve NB Rte 128 traffic destined to NEIC and Highland EB, and traffic originating south of Highland Ave to NB Rte 128	Same

Highland Ave./Needham St.: Future Conditions Technical Report 56b July 1987	RECOMMENDED PLANS TO ADDRESS FUTURE CONDITIONS	CTPS TABLE 5-1d

Appendix A

Correspondence Pertaining to Review of this Report by the Technical Advisory Committee

Appendix A

Description of Content

Upon submission of the first draft of this report to the MDPW, CTPS was directed to distribute copies to the Highland Avenue/ Needham Street Technical Advisory Committee (TAC) for review and comment. This appendix is the correspondence that ensued. Included is a statement of the formal position taken by the TAC with respect to the findings and recommendations presented in the report. In addition, certain views of the MDPW regarding implementation are expressed.

LETTER SENT TO ALL MEMBERS OF THE TECHNICAL ADVISORY COMMITTEE

CTPS

State Transportation Building
10 Park Plaza, Suite 2150
Boston, MA 02116-3968
(617) 973-7100

CENTRAL TRANSPORTATION PLANNING STAFF

December 12, 1986

Mr. Lewis Songer, Executive Vice President
Newton-Needham Chamber of Commerce
437 Cherry Street
Newton, MA 02165

Dear Mr. Songer:

The Massachusetts Department of Public Works (MDPW) has authorized distribution of the enclosed draft report, "Highland Avenue/Needham Street Corridor Traffic Study: Future Conditions" to the membership of the Highland Avenue/Needham Street Technical Advisory Committee (TAC). The MDPW has completed its review and has endorsed the recommendation plan. The report is, however, being circulated as a "draft" so that the comments of the TAC can be included as a part of the finalized report.

As you make your review, please keep in mind that the MDPW will not consider any additional recommendations that have not already been analyzed and proven to be technically feasible in this or the "existing conditions" report, as these reports together comprise the full evaluation of the "Highland Avenue/Needham Street Corridor Consensus Plan." Also note that the implementation of several of the recommendations will require property acquisition initiatives and coordination activities on the part of the municipalities and private interests in the area. These land acquisition activities must precede any activity by the MDPW concerning design and construction of several of the plan components. For example, land acquisition will be required for the realignment of Charles Street at Second Avenue and the internal circulation roads to be developed in conjunction with the reconstruction of Needham Street.

As for the frontage road, the proposed facility is endorsed in concept. It is implicitly recommended for a further, more detailed, analysis within the Route 128 "add-a-lane" project.

It is our belief that the MDPW will seriously consider implementing this plan following endorsement by the TAC. However, these two streets no longer serve a major function in the state highway system. In such situations, the MDPW has been more favorably disposed to funding a project of this magnitude - where a significant capital outlay is involved - when the host communities express the willingness to accept the transference of the improved roadway into municipal ownership at the conclusion of the work.

As always, if you find you have any further questions or need any further information, please do not hesitate to contact us at 973-7100.

Sincerely,

Lawrence H. Tittemore
Lawrence H. Tittemore
Manager of Systems Projects

William T. Steffens
William T. Steffens
Principal Planner

LHT:WTS:od
Enclosure

LEWIS B. SONGER, CCE
Executive Vice President

NEWTON-NEEDHAM CHAMBER OF COMMERCE, INC.
437 CHERRY STREET • NEWTON, MASSACHUSETTS • 02165
AREA CODE 617 • 244-5300

March 24, 1987

Mr. Robert Patenaude, Chief Planner
Massachusetts Department of Public Works
10 Park Plaza
Boston, Massachusetts 02116

Dear Bob:

Thank you for meeting with members of the Technical Advisory Committee and staff members who authored the CTPS Report on Highland Avenue-Needham Street. We all thought it was a productive meeting.

Since that time, the Technical Advisory Committee met for an extended period to draw together our final comments. They are as follows:

We are in agreement:

Frontage Road - We agree with the recommendations and feel that this is absolutely our #1 priority to provide relief and expedite traffic flow.

First Avenue - We agree with the recommendations for Long Term Action.

Highland Avenue - (from Second Avenue to Route 128). We agree assuming there is a five lane width available. Certainly it seems that there is that capability at Second Avenue for channelization.

Second Avenue Intersection - We agree with the east, west and south approach recommendations. (see below for comments on jug handle)

Highland Avenue Bridge - We agree with the recommendations.

Wexford Street Intersection - We agree with the recommendations.

Franklin Street/Reservoir Street - We agree with the recommendations. However, if the railroad bridge is not rebuilt, it is still possible to make a connection on land which is currently not built upon to connect with Reservoir St. We also recommend a traffic light at the intersection with Central Avenue, (See Encl. only if a connecting road to Highland Ave. is built in this area.

Median-u Turns, etc. - We agree with the recommendations.

Oak-Christina Street Intersection - We agree with the recommendations, except that it appears that the alignment will not take place at this time.

(Continued)

Dedham-Winchester Intersection - We agree with the recommendations.

Winchester Street/Route 9 Intersection - We agree with the recommendations.

Centre Street-Route 9 Intersection - We are in agreement with the recommendations.

We are in partial agreement with the following:

Jug-Handle/2nd Avenue/Service Road - We do not disagree with the concept, but on a practical basis cannot identify any way to proce with a right-of-way. We endorse the utilization of First Avenue & A Streets as part of a "ring road" (i.e. "Jug handle") concept in its place.

Needham Street (Oak/Christina to Winchester) - The Committee feels that there is room for a five-lane road in the long-term future. Meanwhile, the re-striping which will give us a continuous left turn will be a very good test for controlling left-hand turns as desired. The committee feels strongly about this three lane (rather than four lane) remedy.

Needham Street (Oak/Christina to Winchester) - We are not opposed to the concept of an interior road. However, it should be noted that there is multiplicity of owners unlikely to agree to the concept. We shall continue to encourage closing curb cuts and any interior circulation plans that can be worked out. Previou discussions with businesses in the area show vehement objection

We are not in agreement with the following:

3rd & 4th Avenue/Kendrick/B Street Extension - We have again examine and discussed the matter and do not see how there can be any "B Street" extension without substantial parking. We do, howev recommend stop signs at Kendrick St. for both 3rd and 4th Avenu

Charles Street/Highland Intersection - We have again looked at the a and do not see as a practical matter how this alignment could take place even if you were to relocate Second Avenue. Major buildings block this remedy.

Please note, however, that we are in strong agreement with prohibiting left-hand turns on Highland Avenue eastbound from Route 128 to Second Avenue. We feel that motorists should be encouraged to use a "ring road" concept--right on First Avenue, left on "A" Street and left on Second to Highland Avenue. Prop signage and enforcement would be required, of course.

(Continued)

Floral Street & Apartment Driveway - We do not agree with the recommendations because of the narrowness of Floral Street, which is highly congested (2 family homes plus rooming houses). To make the plan work, you'd have to take out all parking on one side.

Final Statement: There is unanimity of agreement among the representatives of the Town of Needham, the City of Newton and the Newton-Needham Chamber of Commerce that improvements which will correct the traffic congestion along Needham Street/Highland Avenue and the adjacent area have been identified and can be accomplished in a reasonable time period. To summarize, they are as follows

The Frontage Road - No single piece of recommended action has higher priority than the construction of the frontage road. It affects both communities immensely. Its construction (east of Route 128, northbound) could proceed ahead of the Route 128 widening and provide relief at least five years ahead of the scheduled re-widening process.

Needham Street re-striping and light installation: It is our understanding that there is firm commitment to paint and install this spring. This will provide considerable ease of traffic flow in Newton.

Second Avenue/Highland Avenue: Channelization and signal improvement here is the next issue to be dealt with this year. It would certainly ease traffic flow in Needham. Coordination of lights here and at Oak/Christina will be necessary to avoid gridlock.

Other practical matters that can take place this year:

1. Erect signs that prohibit left turns from Highland Ave. (Route 128 eastbound to 2nd avenue).

2. Erect signage to encourage motorists to utilize First Avenue-A Street-Second Avenue to Highland Avenue as an alternative.

3. Erect stop signs on 3rd & 4th Avenues at Kendrick Street.

Bob, please feel free to call me or write to discuss any statement of our views which may not be clear to you or your associates. Thank you.

Sincerely,

Lewis B. Songer, CCE
Executive Vice President

LBS/mj

Encl.

The Commonwealth of Massachusetts
Executive Office of Transportation and Construction
Department of Public Works
Ten Park Plaza, Boston 02116-3973

April 8, 1987

Mr. Lewis B. Songer
Executive Vice President
Newton-Needham Chamber of Commerce, Inc.
437 Cherry Street
Newton, Massachusetts 02165

Dear Mr. Songer:

We are in receipt of your letter containing comments on behalf of the Highland Avenue-Needham Street Technical Advisory Committee (TAC) concerning the draft CTPS report entitled, "Highland Avenue/Needham Street Corridor Traffic Study: Future Conditions."

We would like to thank you for the speed of your response. From the comprehensiveness of your comments it is clear that the TAC members have have spent a considerable amount of time thinking through the issues involved. It is particularly gratifying to see that the vast majority of the technical solutions proposed by the CTPS staff have been accepted by the committee. Your letter will be incorporated into the final draft of the "Future Conditions" report as an appendix. That report is now being prepared for review and approval by the Sub-Signatory Committee (SSC) of the Metropolitan Planning Organization. Once SSC approval is received the report will be considered as final and printed for mass distribution. We will see to it that CTPS forwards members of the TAC copies of the final report immediately following that printing.

Finally, we would like to thank you and the members of the TAC for their interest, support and advice during this process.

With best regards,

Michael D. Meyer

Dr. Michael D. Meyer
Director, BTP&D

MDM:RHP:dap

cc: Ellen DiGeronimo, Associate Commissioner, MDPW
Robert H. Patneaude, MDPW
Arnold Soolman, CTPS

Appendix B

Consensus Plan of the Highland Avenue/Needham Street Corridor Consensus Committee

Appendix B

Description of Content

In the fall of 1982, municipal officials from the communities of Needham and Newton, working with representatives of the Newton-Needham Chamber of Commerce, formed the Highland Avenue/Needham Street Corridor Consensus Committee. The Committee was formed to respond to a Massachusetts Department of Public Works request of the communities and business interests to formulate an improvement plan for Highland Avenue and Needham Street.

A draft of the agreed-upon plan was submitted to the MDPW on December 17, 1982. That plan, which is now commonly referred to as the Consensus Plan, is contained in this appendix.

NEWTON-NEEDHAM CHAMBER OF COMMERCE, INC.
437 CHERRY STREET • NEWTON, MASSACHUSETTS • 02165
AREA CODE 617 • 244-5300

December 17, 1982

Mr. Sandino J. Tersigni, Commissioner
Massachusetts Department of Public Works
100 Nashua Street
Boston, Massachusetts 02114

Dear Commissioner Tersigni:

At our meeting on September 22, 1982 among you and your staff, officials from the City of Newton and the Town of Needham, representatives of local business and concerned citizens you cited the lack of a consensus on how to improve the Highland Avenue/Needham Street Corridor as a major obstacle for State involvement in the project in the near future. In demonstrating the commitment and concern of the communities and area businesses, we pledged the efforts of our Engineering and Planning staffs and business representatives to develop a consensus, conceptual plan which would serve as the basis for future detailed design and engineering for corridor improvements.

The concept plan, which is attached for your consideration, represents the efforts of the communities and businesses over the past 12 weeks. Five meetings were convened in order to discuss the various components of the project and to achieve resolution.

We believe our efforts have produced a plan which will address the major traffic problems in the Highland Avenue/Needham Street Corridor in a manner which is not only technically feasible, but acceptable.

It is hoped that our efforts have eliminated the lack of consensus on corridor improvements and that we may see further actions taken on this project whose implementation has eluded us for over the past decade.

Very truly yours,

Theodore Mann
Mayor
City of Newton

H. Phillip Garrity
Chairman
Board of Selectmen
Town of Needham

Lewis B. Songer
Exec. Vice President
Newton-Needham
Chamber of Commerce

ACCREDITED

NEWTON-NEEDHAM CHAMBER OF COMMERCE, INC.
437 CHERRY STREET • NEWTON, MASSACHUSETTS • 02165
AREA CODE 617 • 244-5300

December 17, 1982

Needham St.-Highland Ave. Corridor
Transportation Project

-A Concept Plan-

In response to the public meeting held in Needham on Sept. 22nd, attended by public officials from Needham and Newton, leaders of the Newton-Needham Chamber of Commerce and other interested persons, a technical working committee (see attachment #1) was convened to develop a concept plan acceptable to municipal officials and the business community. We believe that, following five working sessions (see attachment #2) we have in fact achieved such a consensus on the issues and the solutions to the problems. The key elements of the concept plan relate to 1) improved access to Route 128; 2) improvements to the Highland Ave. bridge and 3) improvements to Highland Avenue and Needham Street.

1) Improved access to Route 128:

a) There is need to build a frontage road parellel to Route 128 with direct access to streets serving the industrial center, without going as far north as Highland Ave. (See Illustration #1). Minor land taking would allow traffic also to enter this road from Kendrick St., near Coca Cola (keeping traffic off Route 128). This would also allow Wells Ave.-generated traffic to enter 128 northbound without using Second Ave./Highland Ave.

b) There is need to reopen First Ave. and install traffic signals at the Howard Johnson's Restaurant for left-bound turns to allow greater accessibility to the Newton and Needham office and industrial centers.

2) Improvements to the Highland Avenue Bridge:

a) There is need to partially rebuild and widen the bridge over the Charles River by utilizing a cantilevered design to widen the bridge to two lanes in each direction plus sidewalks. The recent reports from the state's Dept. of Bridges show that the superstructure is strong enough to support modifications.

b) In conjunction with the bridge widening, access on the Newton side should be improved by widening the Christina-Oak-Needham St. triad with improved turning capability to facilitate movement (See Illustration #2).

3) Improvements to Highland Ave.-Needham Street

a) Reconstruction of the existing roadway from Route 128 to Route 9 to include construction of a 72' roadway of four lanes (two in each direction) of 12' width with a lane for turning and including sidewalks. (See Illustration #2).

b) Establishment of storage capacity at key points to allow for turning movement of commercial and passenger vehicles.

c) Consolidation of curb cuts where feasible.

d) Encourage the relocation of some loading docks.

e) Encourage additional offstreet parking to permit traffic flow and remove parking on state-owned land.

f) Installation of traffic signals at First Ave., Oak & Christina, Winchester St. and the Centre Street ramps at Route 9 to assure proper traffic flow and increase pedestrian safety.

Summary Focus:

In essence, it is agreed that these improvements meet the needs of business and private traffic, improved access to Route 128 and fr flow of vehicles, as well as providing improved pedestrian safety. Most importantly, it will help preserve existing jobs and allow orderly development for future economic growth. It is to be emphasized that approximately 50% of the private sector jobs are within a two mile radius of this corridor in both communities. It is essential that we preserve what we have and enhance it.

Attachment #1

Technical Committee

Town of Needham- Russell Burke, Planning Director
John Marr, Town Engineer
Richard Robinson, Traffic Engineer

City of Newton- Lewis Branzburg, Economic Development Planner
Barry Canner, Planning Director
Paul Giunta, City Engineer
Donald Quinn, Construction Engineer
Donald Silverson, Director ofEconomic Development
David Tannozzini, Traffic Engineer

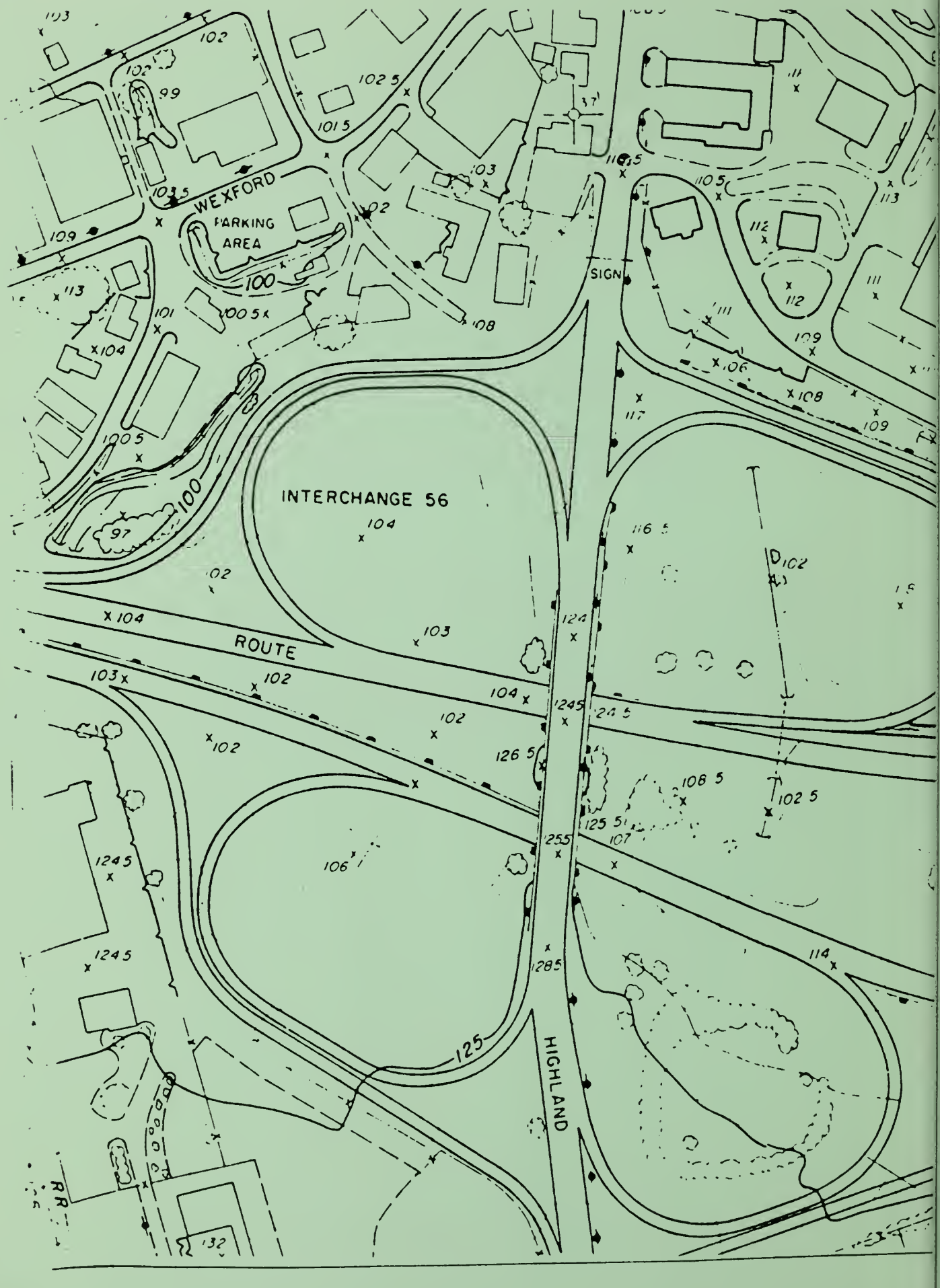
Newton-Needham Chamber of Commerce-

John Fox, GTE Sylvania: Chairman, Highland Ave.-Needham St. Task Force
Stanley Golembe, Itek Corp., Itek Corp.: V.P. Economic Development
Lewis B. Songer, Executive Vice President

Attachment #2

Meeting Schedule (1:30 p.m. meetings)

October 14	Newton City Hall
October 28	Newton City Hall
November 10	Needham Public Works Dept.
November 29	Newton City Hall
December 9	Needham Public Works Dept.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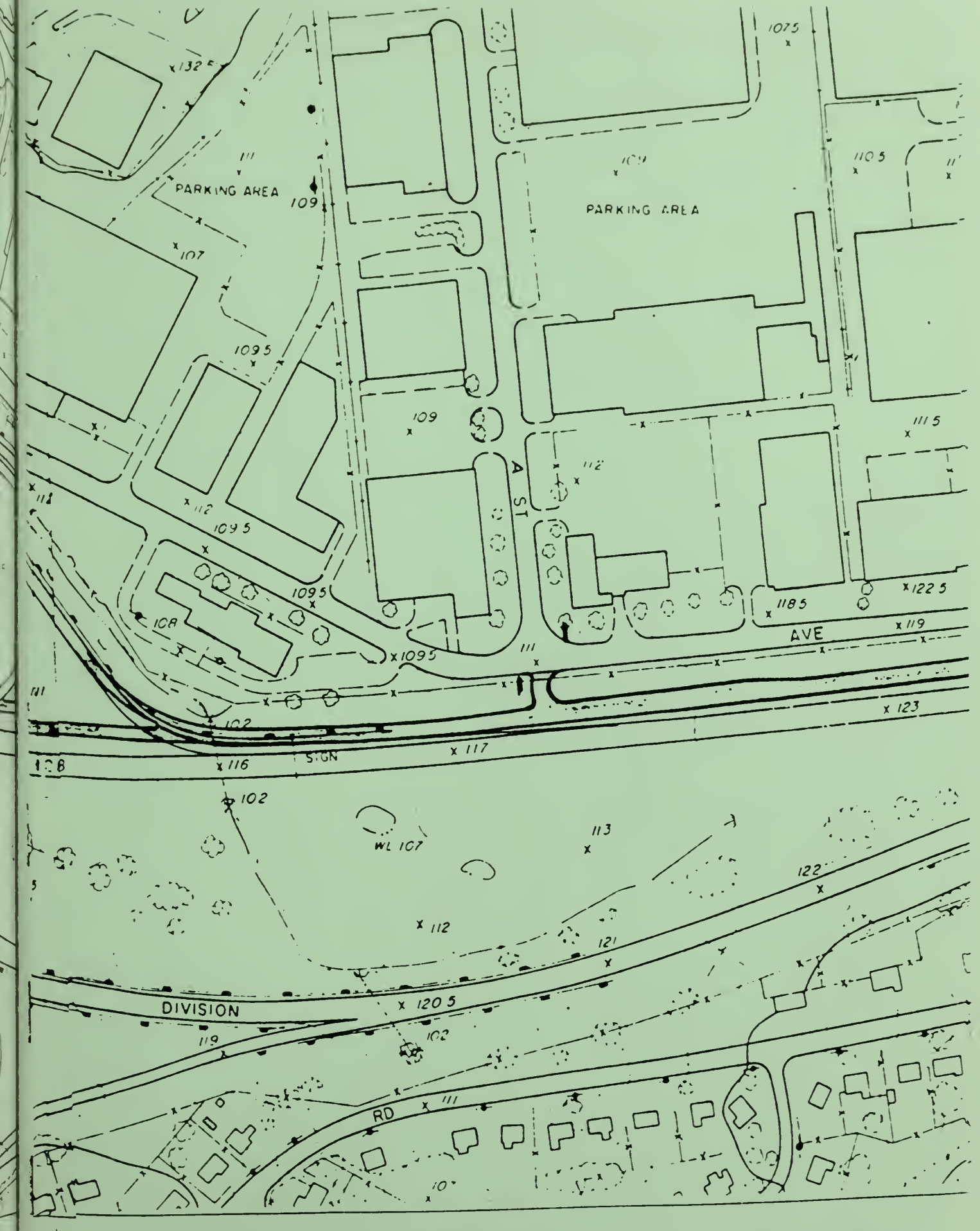
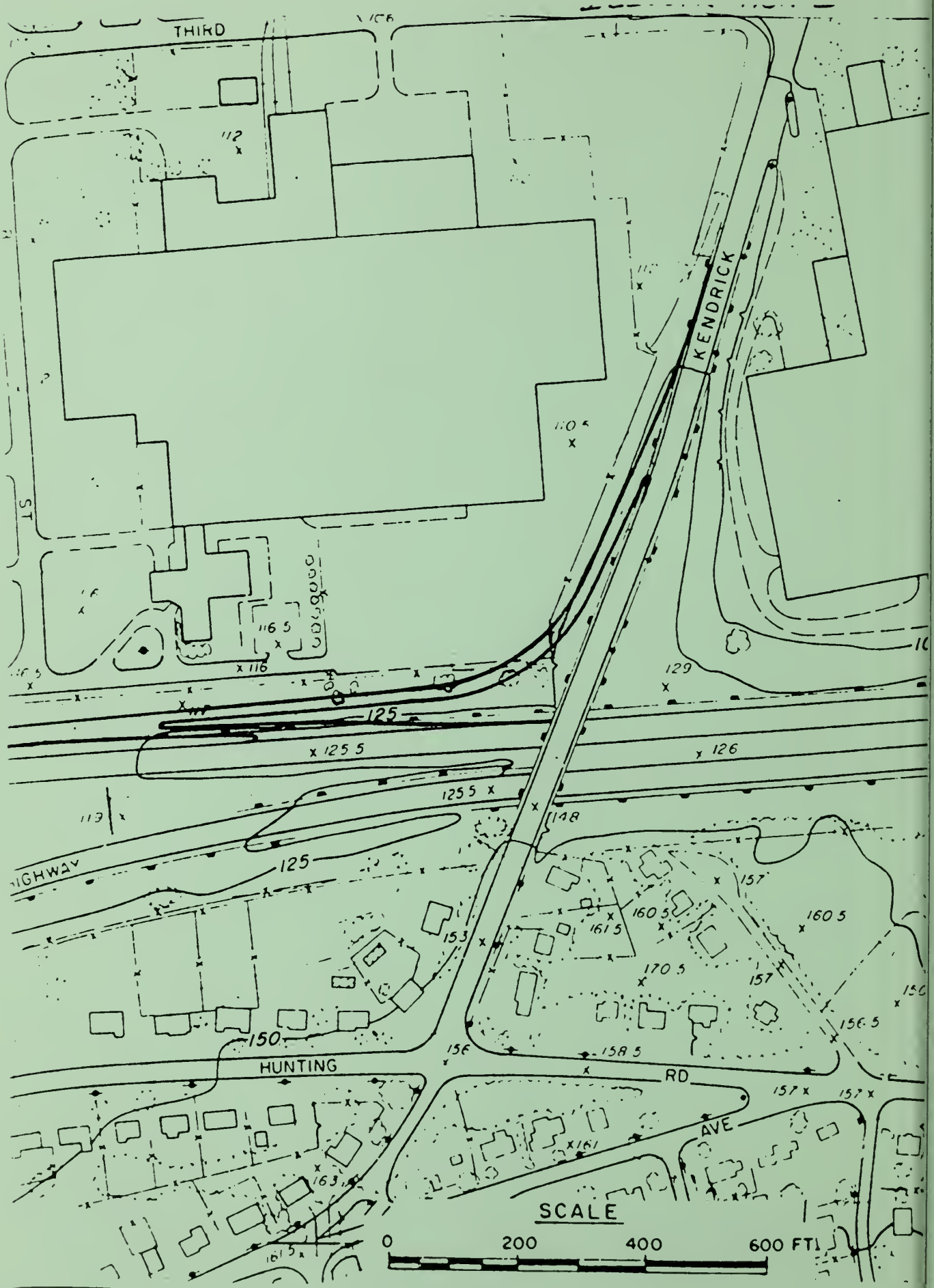
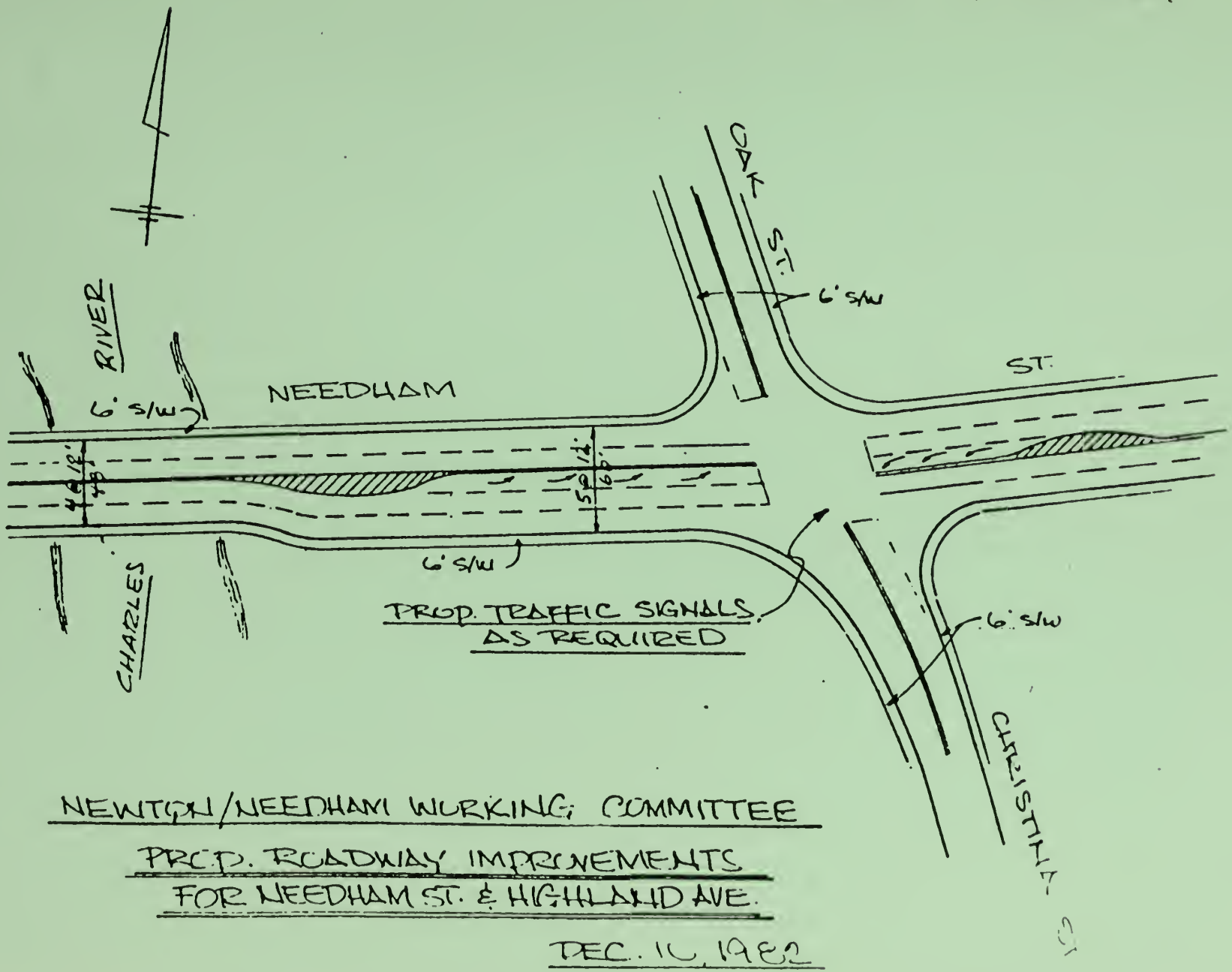
PARKING
AREA
SIGN
INTERCHANGE 56
ROUTE
HIGHLAND
RR


PARKING AREA
PARKING AREA
A ST
AVE
DIVISION
RD
SIGN
WL 107


THIRD
KENDRICK
HUNTING
RD
AVE
HIGHWAY
SCALE
0
200
400
600 FT

NOTE: DETAIL TYPICAL FOR ENTIRE LENGTH OF ROADWAY.



NEWTON/NEEDHAM WORKING COMMITTEE

PROP. ROADWAY IMPROVEMENTS FOR NEEDHAM ST. & HIGHLAND AVE.

DEC. 10, 1982

Appendix C

Town of Needham's Conceptual Drawing of

Frontage Road

Appendix C

Description of Content

As part of the preparation and development of the Highland Avenue/Needham Street Corridor Consensus Committee Plan submitted to the MDPW, the Town of Needham, through Town Engineer John Marr, provided a schematic plan of a frontage road proposal which eventually became a major aspect of the plan. That schematic is shown here at a reduced scale, along with a letter to Mr. Marr indicating to him that the frontage road scheme as drawn would meet accepted horizontal and vertical design criteria.

S BERGER & ASSOCIATES, INC.

Engineers · Economists · Planners
20 William Street, Wellesley, Massachusetts 02181
Telephone (617) 235-5874

December 8, 1982

Mr. John Marr, Jr.
Town Engineer
470 Dedham Avenue
Needham, MA 02192

Attention: Mr. Richard Robinson

Re: Route 128 - Highland Avenue
Needham Industrial Park

Dear Mr. Marr:

As discussed at our meeting in this office on December 2, enclosed please find three copies of a 200 scale plan outlining your scheme for traffic improvements at subject interchange area.

The new roadways, highlighted in yellow, meet current horizontal and vertical design criteria and the scheme definitely appears to be a workable alternative.

Should you have any questions or need additional information, please do not hesitate to call me. We are at your service.

Very truly yours,

LOUIS BERGER & ASSOCIATES, INC.

Harold E. Fitzgerald

Harold E. Fitzgerald
Principal Engineer

HEF:js
enclosures

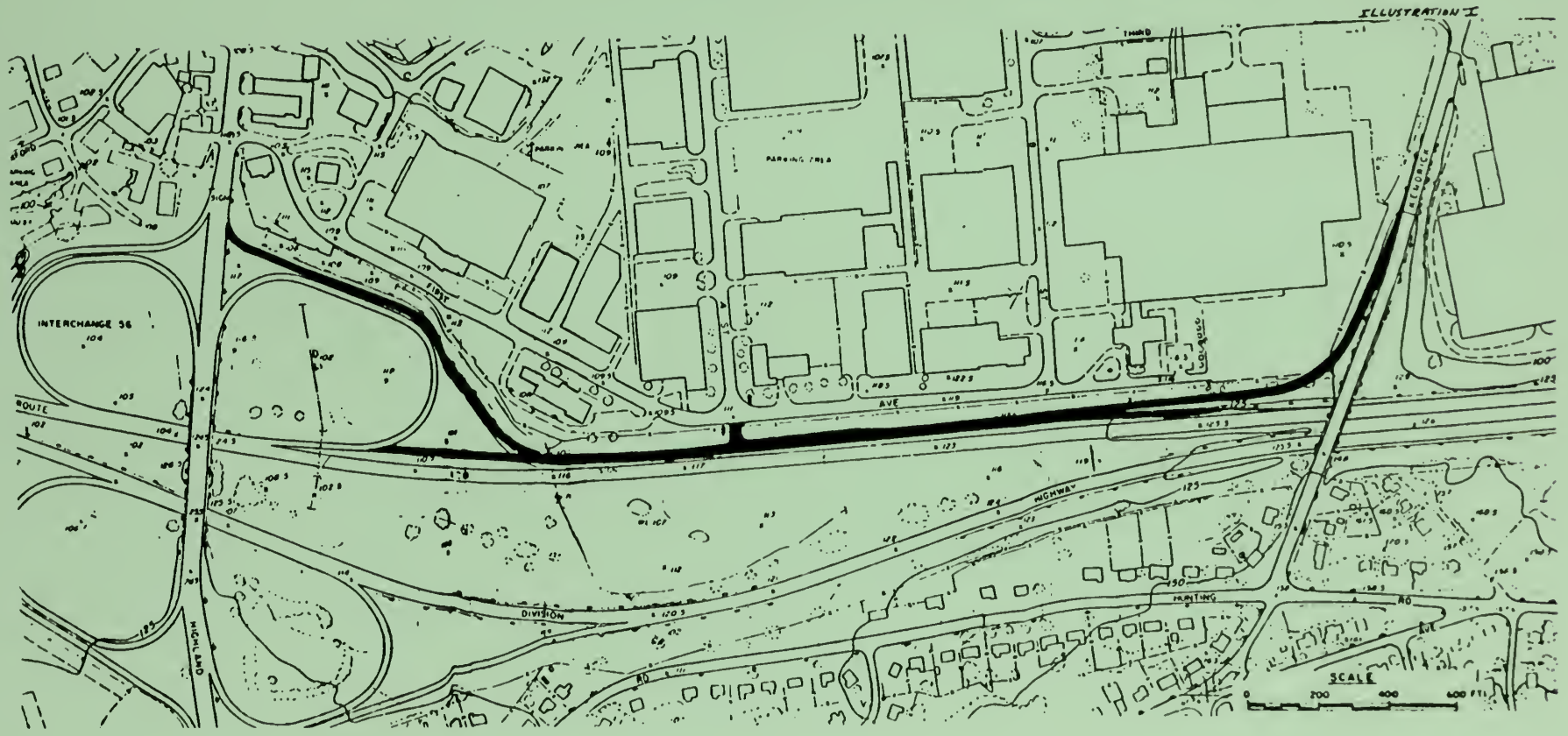


ILLUSTRATION I
INTERCHANGE 56
ROUTE
AVE
HIGHWAY
DIVISION
HUNTING
HIGHLAND
SCALE

Appendix D

Analysis Worksheets for Intersections Affected by Frontage Road/Service Road Alternatives

Appendix D

Description of Content

The introduction of a frontage road, service road or combination of these would divert traffic from presently used paths to the alternate routes provided. The effects on intersection volumes and consequently on levels of service differ depending on which future-year network configuration is eventually implemented.

Intersection capacity analyses were performed at each intersection for which volume changes are anticipated under frontage road/service road scenarios. This appendix contains the worksheet results for 1995 forecast conditions. In those instances where traffic volumes were identical between scenarios, only one set of results is presented.

The intersections analyzed are:

- Highland Avenue at Gould Street and Hunting Road
- Highland Avenue at First Avenue
- Highland Avenue at Wexford
- Highland Avenue at Second Avenue
- Nahanton Street at Jewish (Gosman) Community Campus and Wells Avenue
- Kendrick Street at Fourth Avenue
- Kendrick Street at Third Avenue
- Kendrick Street at Hunting Road

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:10-21-1985 TIME:15:30:24
1995 NO BUILD

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	Gould	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	12	12	11	8
#LT LANES	1	1	0	0
AVG WIDTH	10	10	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	50	544	482	40
THRU VOL	969	1458	538	165
RT VOL	83	321	102	0
PED VOL	5	5	5	5
TRUCK %	2.1	2.1	1.2	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	85	85	85	85
CHANGE INT	42	42	42	42
LT CAP ON CI	85	85	85	85
G/C	.61	.61	.38	.38
OP VOL	1779	1052	165	640
LT CAP ON GR	0	0	291	0
LT TOT CAP	85	85	376	85
LT VOL	50	544	482	40
PASS CHK	Yes	No	No	Yes

STEP SIX OUTPUT

PHF	0.90	0.95	0.90	0.84
LT VOL	57	585	542	48
THRU VOL	1099	1567	605	199
RT VOL	94	345	115	0

STEP SEVEN OUTPUT

OP VOL	1779	1052	165	640
PCE LTU	6.00	6.00	1.00	4.00
PCE LTP	1.05	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	1193	1193
B1 v--	3508	614
A2 <--	1912	1912
A3B4 v '->	1262	1370
B3A4 <-, ^	393	257

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:10-21-1985 TIME:15:30:56
1995 NO BUILD

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	627	627
B1 v--	3508	614
A2 <--	1004	1004
A3B4 v '->	662	719
A4B3 <-, ^	227	149

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

3508	1-one phase only
1618	2-two phase,one left protected,no overlap
1240	3-two phases,one left protected,overlap
1618	4-two phases,both lefts protected,no overlap
1240	5-three phases,both lefts protected,overlap
1677	6-three phases,lead/lag,no overlap
4134	7-three phases,lead/lag,overlap
1630	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

662	1-one phase only
868	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
3	1*	1.11	1903	1720	F
5	1*	1.15	1903	1650	F
5	8	1.28	2108	1650	F
3	8	1.28	2108	1650	F
4	1*	1.33	2280	1720	F
2	1*	1.33	2280	1720	F
8	1*	1.33	2293	1720	F
6	1*	1.42	2340	1650	F
4	8	1.51	2486	1650	F
2	8	1.51	2486	1650	F
8	8	1.51	2498	1650	F
6	8	1.54	2545	1650	F
1*	1*	2.32	4170	1800	F
1*	8	2.54	4376	1720	F
7	1*	2.91	4797	1650	F
7	8	3.03	5002	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:10-21-1985 TIME:15:37:42
1995 FRONTAGE ROAD

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	Gould	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	12	12	11	8
#LT LANES	1	1	0	0
AVG WIDTH	10	10	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	50	527	482	21
THRU VOL	969	1412	538	86
RT VOL	83	311	102	0
PED VOL	5	5	5	5
TRUCK %	2.1	2.1	1.2	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	85	85	85	85
CHANGE INT	42	42	42	42
LT CAP ON CI	85	85	85	85
G/C	.60	.60	.39	.39
OP VOL	1723	1052	86	640
LT CAP ON GR	0	0	382	0
LT TOT CAP	85	85	467	85
LT VOL	50	527	482	21
PASS CHK	Yes	No	No	Yes

STEP SIX OUTPUT

PHF	0.90	0.95	0.90	0.84
LT VOL	57	566	542	25
THRU VOL	1099	1518	605	104
RT VOL	94	334	115	0

STEP SEVEN OUTPUT

OP VOL	1723	1052	86	640
PCE LTU	6.00	6.00	1.00	4.00
PCE LTP	1.05	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	1193	1193
B1 v--	3398	595
A2 <--	1852	1852
A3B4 v *->	1262	1370
B3A4 <-, ^	205	134

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:10-21-1985 TIME:15:38:11
1995 FRONTAGE ROAD

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	627	627
B1 v--	3398	595
A2 <--	972	972
A3B4 v '->	662	719
A4B3 <-, ^	119	78

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

3398	1-one phase only
1567	2-two phase,one left protected,no overlap
1221	3-two phases,one left protected,overlap
1567	4-two phases,both lefts protected,no overlap
1221	5-three phases,both lefts protected,overlap
1626	6-three phases,lead/lag,no overlap
4025	7-three phases,lead/lag,overlap
1599	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

662	1-one phase only
797	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
3	1*	1.10	1884	1720	F
5	1*	1.14	1884	1650	F
5	8	1.22	2018	1650	F
3	8	1.22	2018	1650	F
4	1*	1.30	2229	1720	F
2	1*	1.30	2229	1720	F
8	1*	1.31	2261	1720	F
6	1*	1.39	2289	1650	F
4	8	1.43	2364	1650	F
2	8	1.43	2364	1650	F
8	8	1.45	2396	1650	F
6	8	1.47	2423	1650	F
1*	1*	2.26	4061	1800	F
1*	8	2.44	4195	1720	F
7	1*	2.84	4687	1650	F
7	8	2.92	4822	1650	F

* This phasing may be inappropriate due to left turn restrictions see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:10-21-1985 TIME:15:32:06
1995 SERVICE LOOP

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	Gould	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	12	12	11	8
#LT LANES	1	1	0	0
AVG WIDTH	10	10	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	50	544	482	40
THRU VOL	969	1458	538	165
RT VOL	83	321	102	0
PED VOL	5	5	5	5
TRUCK %	2.1	2.1	1.2	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	85	85	85	85
CHANGE INT	42	42	42	42
LT CAP ON CI	85	85	85	85
G/C	.61	.61	.38	.38
OP VOL	1779	1052	165	640
LT CAP ON GR	0	0	291	0
LT TOT CAP	85	85	376	85
LT VOL	50	544	482	40
PASS CHK	Yes	No	No	Yes

STEP SIX OUTPUT

PHF	0.90	0.95	0.90	0.84
LT VOL	57	585	542	48
THRU VOL	1099	1567	605	199
RT VOL	94	345	115	0

STEP SEVEN OUTPUT

OP VOL	1779	1052	165	640
PCE LTU	6.00	6.00	1.00	4.00
PCE LTP	1.05	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	1193	1193
B1 v--	3508	614
A2 <--	1912	1912
A3B4 v '->	1262	1370
B3A4 <-, ^	393	257

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:10-21-1985 TIME:15:32:47
1995 SERVICE LOOP

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	627	627
B1 v--	3508	614
A2 <--	1004	1004
A3B4 v `->	662	719
A4B3 <-, ^	227	149

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

3508	1-one phase only
1618	2-two phase,one left protected,no overlap
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1630	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

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5	1*	1.15	1903	1650	F
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3	8	1.28	2108	1650	F
4	1*	1.33	2280	1720	F
2	1*	1.33	2280	1720	F
8	1*	1.33	2293	1720	F
6	1*	1.42	2340	1650	F
4	8	1.51	2486	1650	F
2	8	1.51	2486	1650	F
8	8	1.51	2498	1650	F
6	8	1.54	2545	1650	F
1*	1*	2.32	4170	1800	F
1*	8	2.54	4376	1720	F
7	1*	2.91	4797	1650	F
7	8	3.03	5002	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:10-21-1985 TIME:15:39:16
1995 FRONTAGE ROAD/SERVICE LOOP

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	Gould	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	12	12	11	8
#LT LANES	1	1	0	0
AVG WIDTH	10	10	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	50	527	482	21
THRU VOL	969	1412	538	86
RT VOL	83	311	102	0
PED VOL	5	5	5	5
TRUCK %	2.1	2.1	1.2	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	85	85	85	85
CHANGE INT	42	42	42	42
LT CAP ON CI	85	85	85	85
G/C	.60	.60	.39	.39
OP VOL	1723	1052	86	640
LT CAP ON GR	0	0	382	0
LT TOT CAP	85	85	467	85
LT VOL	50	527	482	21
PASS CHK	Yes	No	No	Yes

STEP SIX OUTPUT

PHF	0.90	0.95	0.90	0.84
LT VOL	57	566	542	25
THRU VOL	1099	1518	605	104
RT VOL	94	334	115	0

STEP SEVEN OUTPUT

OP VOL	1723	1052	86	640
PCE LTU	6.00	6.00	1.00	4.00
PCE LTP	1.05	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	1193	1193
B1 v--	3398	595
A2 <--	1852	1852
A3B4 v '->	1262	1370
B3A4 <-, ^	205	134

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)

DATE:10-21-1985 TIME:15:39:51

1995 FRONTAGE ROAD/SERVICE LOOP

STEP EIGHT AND NINE A OUTPUT

	BNPROTECT LT	PROTECT LT
B2 --^	340	60
A1 -->	627	627
B1 v--	3398	595
A2 <--	972	972
A3B4 v '->	662	719
A4B3 <-, ^	119	78

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

3398	1-one phase only
1567	2-two phase,one left protected,no overlap
1221	3-two phases,one left protected,overlap
1567	4-two phases,both lefts protected,no overlap
1221	5-three phases,both lefts protected,overlap
1626	6-three phases,lead/lag,no overlap
4025	7-three phases,lead/lag,overlap
1599	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

662	1-one phase only
797	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
3	1*	1.10	1884	1720	F
5	1*	1.14	1884	1650	F
5	8	1.22	2018	1650	F
3	8	1.22	2018	1650	F
4	1*	1.30	2229	1720	F
2	1*	1.30	2229	1720	F
8	1*	1.31	2261	1720	F
6	1*	1.39	2289	1650	F
4	8	1.43	2364	1650	F
2	8	1.43	2364	1650	F
8	8	1.45	2396	1650	F
6	8	1.47	2423	1650	F
1*	1*	2.26	4061	1800	F
1*	8	2.44	4195	1720	F
7	1*	2.84	4687	1650	F
7	8	2.92	4822	1650	F

* This phasing may be inappropriate due to left turn restrictions see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:07-22-1985 TIME:08:51:53
1995 NO BUILD

GENERAL CHARACTERISTICS
CONTROLS: STOP
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: First
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: Highland			B: Highland			C: First		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	1273	248	0	0	0	0	0	297
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	95.00			99.00			%100.00		
PERCENT LT TRU	2.00			0.00			0.00		
PERCENT HV TRU	3.00			1.00			0.00		
PASS CAR/HR	0			0			0	0	297

STEP 1 RIGHT TURNS FROM	C:First
CONFLICTING FLOWS	761
CRITICAL GAPS	6.0
CAPACITY	390
DEMAND	297
SHARED LANE	N
AVAILABLE RESERVE	93
DELAY	Very long delay
LOS	E

STEP 2 LEFT TURNS FROM	B:Highland
CONFLICTING FLOWS	1521
CRITICAL GAPS	5.5
CAPACITY	191
DEMAND	0
CAPACITY USED	0
IMPEDANCE FACTOR	1.00
AVAILABLE RESERVE	191
DELAY	Long delay
LOS	D

STEP 3 LEFT TURNS FROM	C:First
CONFLICTING FLOWS	1397
CRITICAL GAPS	8.0
CAPACITY	72
ADJUST FOR IMP	72
SHARED LANE RIGHT	N
DEMAND	0
AVAILABLE RESERVE	72
DELAY	Very long delay
LOS	E

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
RT FROM C:	297	390	93	E

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:07-22-1985 TIME:09:02:34
1995 Frontage Road

GENERAL CHARACTERISTICS
CONTROLS: STOP
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: First
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: Highland			B: Highland			C: First		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	1157	225	0	0	0	0	0	891
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	95.00			99.00			%100.00		
PERCENT LT TRU	2.00			0.00			0.00		
PERCENT HV TRU	3.00			1.00			0.00		
PASS CAR/HR	0			0			0	0	891

STEP 1 RIGHT TURNS FROM	C:First
CONFLICTING FLOWS	891
CRITICAL GAPS	6.0
CAPACITY	426
DEMAND	891
SHARED LANE	N
AVAILABLE RESERVE	-465
DELAY	Failure
LOS	E*

STEP 2 LEFT TURNS FROM	B:Highland
CONFLICTING FLOWS	1382
CRITICAL GAPS	5.5
CAPACITY	224
DEMAND	0
CAPACITY USED	0
IMPEDANCE FACTOR	1.00
AVAILABLE RESERVE	224
DELAY	Average delay
LOS	C

STEP 3 LEFT TURNS FROM	C:First
CONFLICTING FLOWS	1270
CRITICAL GAPS	8.0
CAPACITY	90
ADJUST FOR IMP	90
SHARED LANE RIGHT	N
DEMAND	0
AVAILABLE RESERVE	90
DELAY	Very long delay
LOS	E

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
RT FROM C:	891	426	-465	E*

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:08-06-1985 TIME:09:49:27
1995 Frontage Road with Improvements

P.M. Peak Hour

GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: Wexford
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: Highland			B: Highland			C: Wexford		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	2196	31	127	1270	0	47	0	268
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	98.00			97.00			98.00		
PERCENT LT TRU	1.00			1.00			1.00		
PERCENT HV TRU	1.00			2.00			1.00		
PASS CAR/HR	0			130			50	0	272

STEP 1 RIGHT TURNS FROM C:Wexford

CONFLICTING FLOWS	1114
CRITICAL GAPS	5.0
CAPACITY	379
DEMAND	272
SHARED LANE	N
AVAILABLE RESERVE	107
DELAY	Long delay
LOS	D

STEP 2 LEFT TURNS FROM B:Highland

CONFLICTING FLOWS	2227
CRITICAL GAPS	5.5
CAPACITY	84
DEMAND	130
CAPACITY USED	155
IMPEDANCE FACTOR	0.00
AVAILABLE RESERVE	-46
DELAY	Failure
LOS	E*

STEP 3 LEFT TURNS FROM C:Wexford

CONFLICTING FLOWS	3409
CRITICAL GAPS	7.0
CAPACITY	4
ADJUST FOR IMP	0
SHARED LANE RIGHT	N
DEMAND	50
AVAILABLE RESERVE	-50
DELAY	Failure
LOS	E*

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	130	84	-46	E*
LT FROM C:	50	4	-50	E*
RT FROM C:	272	379	107	D

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:08-06-1985 TIME:09:51:55
1995 Service Loop with Improvements

P.M. Peak Hour

GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: Wexford
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: Highland			B: Highland			C: Wexford		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	2784	40	120	1200	0	49	0	268
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	98.00			97.00			98.00		
PERCENT LT TRU	1.00			1.00			1.00		
PERCENT HV TRU	1.00			2.00			1.00		
PASS CAR/HR	0			123			51	0	277

STEP 1 RIGHT TURNS FROM	C:Wexford
CONFLICTING FLOWS	1412
CRITICAL GAPS	5.0
CAPACITY	276
DEMAND	272
SHARED LANE	N
AVAILABLE RESERVE	4
DELAY	Very long delay
LOS	E

STEP 2 LEFT TURNS FROM	B:Highland
CONFLICTING FLOWS	2824
CRITICAL GAPS	5.5
CAPACITY	42
DEMAND	123
CAPACITY USED	292
IMPEDANCE FACTOR	0.00
AVAILABLE RESERVE	-81
DELAY	Failure
LOS	E*

STEP 3 LEFT TURNS FROM	C:Wexford
CONFLICTING FLOWS	4124
CRITICAL GAPS	7.0
CAPACITY	2
ADJUST FOR IMP	0
SHARED LANE RIGHT	N
DEMAND	50
AVAILABLE RESERVE	-50
DELAY	Failure
LOS	E*

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	123	42	-81	E*
LT FROM C:	50	2	-50	E*
RT FROM C:	272	276	4	E

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:08-06-1985 TIME:09:56:20
1995 Frontage Road/Service Loop with Improvements

P.M. Peak Hour

GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: Wexford
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: Highland			B: Highland			C: Wexford		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	2464	35	113	1134	0	49	0	268
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	98.00			97.00			98.00		
PERCENT LT TRU	1.00			1.00			1.00		
PERCENT HV TRU	1.00			2.00			1.00		
PASS CAR/HR	0			116			50	0	272

STEP 1 RIGHT TURNS FROM	C:Wexford
CONFLICTING FLOWS	1250
CRITICAL GAPS	5.0
CAPACITY	328
DEMAND	272
SHARED LANE	N
AVAILABLE RESERVE	56
DELAY	Very long delay
LOS	E

STEP 2 LEFT TURNS FROM	B:Highland
CONFLICTING FLOWS	2499
CRITICAL GAPS	5.5
CAPACITY	61
DEMAND	116
CAPACITY USED	189
IMPEDANCE FACTOR	0.00
AVAILABLE RESERVE	-54
DELAY	Failure
LOS	E*

STEP 3 LEFT TURNS FROM	C:Wexford
CONFLICTING FLOWS	3729
CRITICAL GAPS	7.0
CAPACITY	4
ADJUST FOR IMP	0
SHARED LANE RIGHT	N
DEMAND	50
AVAILABLE RESERVE	-50
DELAY	Failure
LOS	E*

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	116	61	-54	E*
LT FROM C:	50	4	-50	E*
RT FROM C:	272	328	56	E

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)

DATE:01-01-1990 TIME:08:58:10

1995 NO BUILD with Left on Highland Right on Second. P.M. PEAK HOUR

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	N/A	Second Ave.
#THRU LANES	2	2	1	2
AVG WIDTH	12	11	10	11
#LT LANES	0	1	0	0
AVG WIDTH	0	10	0	0
#RT LANES	0	0	0	1
AVG WIDTH	0	0	0	10

STEP TWO OUTPUT

LT VOL	0	76	0	1046
THRU VOL	1144	1324	0	0
RT VOL	154	0	0	146
PED VOL	0	0	0	6
TRUCK %	3.4	1.6	0.0	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	68	68	68	66
CHANGE INT	53	53	53	53
LT CAP ON CI	106	106	106	106
G/C	.55	.55	.44	.44
OP VOL	1324	1298	146	0
LT CAP ON GR	0	0	382	528
LT TOT CAP	106	106	488	634
LT VOL	0	76	0	1046
PASS CHK	Yes	Yes	Yes	No

STEP SIX OUTPUT

PHF	0.91	0.89	0.00	0.86
LT VOL	0	87	0	1215
THRU VOL	1300	1511	0	0
RT VOL	175	0	0	172

STEP SEVEN OUTPUT

OP VOL	1324	1298	146	0
PCE LTU	6.00	6.00	1.00	1.00
PCE LTP	1.20	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	1511	1511
A1B2 --> --^	1475	1475
B3A4 <-, ^	1235	1481

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:01-01-1980 TIME:08:58:46
1995 NO BUILD with xleft on Highland xright on Second.

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	794	794
A1B2 --> --^	774	774
A4B3 <-. ^	648	778

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

794	1-one phase only
885	2-two phase,one left protected,no overlap
965	3-two phases,one left protected,overlap
1568	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

648	1-one phase only
778	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1	1*	0.80	1442	1800	D
3	1*	0.88	1514	1720	D
2	1*	0.89	1533	1720	E
1	8	0.91	1571	1720	E
3	8	1.00	1643	1650	E
2	8	1.01	1662	1650	F
8	1*	1.29	2216	1720	F
8	8	1.42	2346	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)

DATE:08-06-1985 TIME:09:01:48

1995 Frontage Road with Improvements PM Peak Hour

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	None	Second
#THRU LANES	2	2	0	2
AVG WIDTH	12	11	10	11
#LT LANES	0	1	0	0
AVG WIDTH	0	10	0	0
#RT LANES	0	0	0	1
AVG WIDTH	0	0	0	10

STEP TWO OUTPUT

LT VOL	0	76	0	665
THRU VOL	1084	1324	0	0
RT VOL	146	0	0	146
PED VOL	0	0	0	6
TRUCK %	3.4	1.6	0.0	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	68	68	68	68
CHANGE INT	53	53	53	53
LT CAP ON CI	106	106	106	106
G/C	.66	.66	.33	.33
OP VOL	1324	1230	146	0
LT CAP ON GR	0	0	250	396
LT TOT CAP	106	106	356	502
LT VOL	0	76	0	665
PASS CHK	Yes	Yes	Yes	No

STEP SIX OUTPUT

PHF	0.91	0.89	0.00	0.86
LT VOL	0	87	0	785
THRU VOL	1232	1511	0	0
RT VOL	166	0	0	172

STEP SEVEN OUTPUT

OP VOL	1324	1230	146	0
PCE LTU	6.00	6.00	1.00	1.00
PCE LTP	1.20	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	1511	1511
A1B2 --> --^	1398	1398
B3A4 <-, ^	785	942

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:08-06-1985 TIME:09:02:15
1995 Frontage Road with Improvements

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	794	794
A1B2 --> --^	734	734
A4B3 <-, ^	412	494

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

794	1-one phase only
885	2-two phase,one left protected,no overlap
825	3-two phases,one left protected,overlap
1527	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

412	1-one phase only
494	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1	1*	0.67	1206	1800	B
3	1*	0.72	1237	1720	C
1	8	0.75	1288	1720	C
2	1*	0.75	1297	1720	C
3	8	0.80	1319	1650	D
2	8	0.84	1379	1650	D
8	1*	1.13	1939	1720	F
8	8	1.23	2022	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)

DATE:08-06-1985 TIME:09:27:26

1995 Service Loop with Improvements P.M Peak Hour

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	None	Second
#THRU LANES	2	2	0	2
AVG WIDTH	12	11	10	11
#LT LANES	0	1	0	0
AVG WIDTH	0	10	0	0
#RT LANES	0	0	0	1
AVG WIDTH	0	0	0	10

STEP TWO OUTPUT

LT VOL	0	76	0	1239
THRU VOL	1143	1324	0	0
RT VOL	154	0	0	176
PED VOL	0	0	0	6
TRUCK %	3.4	1.6	0.0	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT ,

CYCLE(secs)	68	68	68	68
CHANGE INT	53	53	53	53
LT CAP ON CI	106	106	106	106
G/C	.51	.51	.48	.48
OP VOL	1324	1297	176	0
LT CAP ON GR	0	0	400	576
LT TOT CAP	106	106	506	682
LT VOL	0	76	0	1239
PASS CHK	Yes	Yes	Yes	No

STEP SIX OUTPUT

PHF	0.91	0.89	0.00	0.86
LT VOL	0	87	0	1462
THRU VOL	1299	1511	0	0
RT VOL	175	0	0	208

STEP SEVEN OUTPUT

OP VOL	1324	1297	176	0
PCE LTU	6.00	6.00	1.00	1.00
PCE LTP	1.20	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
31 v--	521	91
A2 <--	1511	1511
A1B2 --> --^	1474	1474
93A4 <-, ^	1462	1755

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:08-06-1985 TIME:09:28:10
1995 Service Loop with Improvements

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	794	794
A1B2 --> ---^	774	774
A4B3 <-, ^	768	921

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

794	1-one phase only
885	2-two phase,one left protected,no overlap
865	3-two phases,one left protected,overlap
1567	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

768	1-one phase only
921	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1	1*	0.87	1561	1800	D
3	1*	0.95	1633	1720	E
2	1*	0.96	1652	1720	E
1	8	1.00	1715	1720	E
3	8	1.08	1786	1650	F
2	8	1.09	1806	1650	F
8	1*	1.36	2335	1720	F
8	8	1.51	2488	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)

DATE:08-06-1985 TIME:09:30:02

1995 Frontage Road/Service Loop with Improvements P.M. Peak Hour

STEP ONE OUTPUT

	1	2	3	4
NAME	Highland	Highland	None	Second
#THRU LANES	2	2	0	2
AVG WIDTH	12	11	10	11
#LT LANES	0	1	0	0
AVG WIDTH	0	10	0	0
#RT LANES	0	0	0	1
AVG WIDTH	0	0	0	10

STEP TWO OUTPUT

LT VOL	0	76	0	796
THRU VOL	1083	1324	0	0
RT VOL	146	0	0	246
PED VOL	0	0	0	6
TRUCK %	3.4	1.6	0.0	1.5
BUS STOP	0	0	0	0

STEP FOUR OUTPUT,

CYCLE(secs)	68	68	68	68
CHANGE INT	53	53	53	53
LT CAP ON CI	106	106	106	106
G/C	.62	.62	.37	.37
OP VOL	1324	1229	246	0
LT CAP ON GR	0	0	198	444
LT TOT CAP	106	106	304	550
LT VOL	0	76	0	796
PASS CHK	Yes	Yes	Yes	No

STEP SIX OUTPUT

PHF	0.91	0.89	0.00	0.86
LT VOL	0	87	0	939
THRU VOL	1231	1511	0	0
RT VOL	166	0	0	290

STEP SEVEN OUTPUT

OP VOL	1324	1229	246	0
PCE LTU	6.00	6.00	1.00	1.00
PCE LTP	1.20	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	1511	1511
A1B2 --> --^	1396	1396
B2A4 <-, ^	939	1127

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:08-06-1985 TIME:09:30:46
1995 Frontage Road/Service Loop with Improvements

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B1 v--	521	91
A2 <--	794	794
A1B2 --> --^	733	733
A4B3 <-, ^	493	592

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

794	1-one phase only
885	2-two phase,one left protected,no overlap
824	3-two phases,one left protected,overlap
1527	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

493	1-one phase only
592	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1	1*	0.71	1287	1800	C
3	1*	0.77	1317	1720	C
2	1*	0.80	1378	1720	D
1	8	0.81	1385	1720	D
3	8	0.86	1416	1650	D
2	8	0.89	1476	1650	E
8	1*	1.17	2020	1720	F
8	8	1.28	2119	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 2 APPROACHES
DATE:10-18-1995 TIME:11:55:28
1995 FRONTAGE ROAD WITH ONE-WAY INBOUND AND SIGNAL AT TWIFO IMPROVEMENTS

GENERAL CHARACTERISTICS
CONTROLS: STOP
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: FOURTH
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: KENDRICK			B: KENDRICK			C: FOURTH		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	1011	360	76	946	0	0	0	0
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	99.00			99.00			0.00		
PERCENT LT TRU	0.00			0.00			0.00		
PERCENT HV TRU	1.00			1.00			0.00		
PASS CAR/HR	0			77			0	0	0

STEP 1 RIGHT TURNS FROM C:FOURTH
CONFLICTING FLOWS 946
CRITICAL GAPS 6.5
CAPACITY 429
DEMAND 0
SHARED LANE .
AVAILABLE RESERVE 429
DELAY Little or no delay
LOS A

STEP 2 LEFT TURNS FROM B:KENDRICK
CONFLICTING FLOWS 1371
CRITICAL GAPS 6.5
CAPACITY 227
DEMAND 77
CAPACITY USED 34
IMPEDANCE FACTOR 0.74
AVAILABLE RESERVE 150
DELAY Long delay
LOS D

STEP 3 LEFT TURNS FROM C:FOURTH
CONFLICTING FLOWS 2217
CRITICAL GAPS 6.5
CAPACITY 18
ADJUST FOR IMP 12
SHARED LANE RIGHT N
DEMAND 0
AVAILABLE RESERVE 12
DELAY Very long dela.
LOS F

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	77	227	150	D

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:10-19-1995 TIME:11:59:00
1995 NO BUILD WITH ONE-WAY INBOUND AND SIGNAL AT THIRD AVE IMPROVEMENTS

GENERAL CHARACTERISTICS
CONTROLS: STOP
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: FOURTH
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: KENDRICK			B: KENDRICK			C: FOURTH		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	1031	340	76	911	0	0	0	0
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	99.00			99.00			0.00		
PERCENT LT TRU	0.00			0.00			0.00		
PERCENT HV TRU	1.00			1.00			0.00		
PASS CAR/HR	0			77			0	0	0

STEP 1 RIGHT TURNS FROM	C:FOURTH
CONFLICTING FLOWS	886
CRITICAL GAPS	6.0
CAPACITY	414
DEMAND	0
SHARED LANE	N
AVAILABLE RESERVE	414
DELAY	Little or no delay
LOS	A

STEP 2 LEFT TURNS FROM	B:KENDRICK
CONFLICTING FLOWS	1371
CRITICAL GAPS	5.5
CAPACITY	237
DEMAND	77
CAPACITY USED	33
IMPEDANCE FACTOR	0.74
AVAILABLE RESERVE	150
DELAY	Long delay
LOS	D

STEP 3 LEFT TURNS FROM	C:FOURTH
CONFLICTING FLOWS	2188
CRITICAL GAPS	6.0
CAPACITY	19
ADJUST FOR IMP	14
SHARED LANE RIGHT	N
DEMAND	0
AVAILABLE RESERVE	14
DELAY	Very long delay
LOS	E

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	77	227	150	D

DATE:10-10-1985 TIME:11:27:17
NO BUILD 1985 WITH SIGNAL AND ONE-WAY IMPROVEMENTS

STEP ONE OUTPUT

NAME	1 MENOMINEE	2 MENOMINEE	3 THIRD	4
#THRU LANES	2	2	0	0
AVG WIDTH	12	12	12	12
#LT LANES	0	0	1	0
AVG WIDTH	0	0	15	0
#RT LANES	0	0	1	0
AVG WIDTH	0	0	15	0

STEP TWO OUTPUT

LT VOL	0	0	286	0
THRU VOL	545	1112	0	0
RT VOL	0	0	724	0
PED VOL	0	0	0	0
TRUCK %	0.0	1.8	1.7	2.0
AVG STOP	1	1	1	0

STEP FOUR OUTPUT

CYCLE(secs)	60	60	60	60
CHANGE INT	60	60	60	60
LT CAP ON CI	120	120	120	120
V/C	.47	.47	.71	.54
OP VOL	1112	545	0	724
LT CAP ON OP	0	0	170	0
LT TOT CAP	120	120	737	120
LT VOL	0	0	786	0
PASS CHK	Yes	Yes	Yes	Yes

STEP SIX OUTPUT

PHF	0.87	0.80	0.84	1.10
LT VOL	0	0	322	0
THRU VOL	626	1403	0	0
RT VOL	0	0	1169	0

STEP SEVEN OUTPUT

OP VOL	1112	545	0	724
PCE LTU	4.00	2.00	1.00	4.00
PCE LTP	1.20	1.20	1.05	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B4 '->	629	459
A1B2 --> --^	626	626
A2B1 <-- v--	1403	1403

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN PAGE 1
(C)
DATE:10-18-1995 TIME:11:38:02
NO BUILD 1995 WITH SIGNAL AND CUL-DE-SAC IMPROVEMENTS

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
84 <->	345	593
43 v **	1052	1052
A182 --> --^	329	329
A281 <-- v--	736	736

** The critical lane volume occurs in the exclusive right turn lane(s)

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

736	1-one phase only
1065	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

1052	1-one phase only
1645	2-two phase,one left protected,no overlap
1052	7-two phases,one left protected,overlap
1052	9-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM I'	Capacity	LOS
1	1	0.99	1781	1801	E
1	7	1.04	1799	1731	F
1	9	1.04	1792	1731	F
8	1	1.22	2117	1731	F
8	8	1.22	2117	1650	F
8	7	1.28	2117	1650	F
8	8	1.38	2381	1726	F
8	2	1.64	2710	1650	F

DATE:10-18-1995 TIME:11:29:17
1995 FRONTAGE ROAD WITH SIGNAL AND ONE-WAY IMPROVEMENTS

STEP ONE OUTPUT

	1	2	3	4
NAME	LENDRICK	VENDRICK	T-1?0	
#THRU LANES	2	2	0	0
AVG WIDTH	12	12	12	12
#LT LANES	0	0	1	0
AVG WIDTH	0	0	15	0
#RT LANES	0	0	1	0
AVG WIDTH	0	0	15	0

STEP TWO OUTPUT

LT VOL	0	0	525	0
THRU VOL	545	1774	0	0
RT VOL	0	0	1324	0
PED VOL	0	0	0	0
TRUCK %	0.0	0.0	7.7	0.0
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	80	80	80	80
CHANGE INT	10	10	10	10
LT CAP ON CI	120	120	120	120
G/C	.40	.21	.60	.60
OP VOL	1776	545	0	1324
LT CAP ON OR	0	0	720	0
LT TOT CAP	120	120	840	120
LT VOL	0	0	525	0
PASS CHK	Yes	Yes	Yes	Yes

STEP SIX OUTPUT

V/C	0.87	0.80	0.54	0.00
LT VOL	0	0	918	0
THRU VOL	776	2240	0	0
RT VOL	0	0	2317	0

STEP SEVEN OUTPUT

OP VOL	1776	545	0	1324
PCE LTU	6.00	2.00	1.00	6.00
PCE LTP	1.20	1.20	1.05	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B4 <->	815	956
A1B2 --> --^	626	626
A2B1 <-- v--	2240	2240

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:10-18-1985 TIME:11:40:11
1995 FRONTAGE ROAD WITH SIGNAL AND ONE-WAY IMPROVEMENTS

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
54 '->	734	770
A3 v **	1923	1923
A1B2 --> --^	329	329
A2B1 <-- v--	1176	1176

** The critical lane volume occurs in the exclusive right turn lane(s)

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

1176 1-one phase only
1505 8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

1923 1-one phase only
3694 2-two phase,one left protected,no overlap
1927 3-two phases,one left protected,overlap
1927 8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1	1	1.72	3094	1800	F
1	3	1.90	3099	1720	F
1	8	1.90	3097	1720	F
8	1	1.99	3428	1720	F
8	8	2.08	3433	1650	F
8	3	2.08	3428	1650	F
1	1	2.25	3870	1720	F
8	2	2.54	4198	1650	F

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:07-19-1985 TIME:09:39:15
1995 NO BUILD

STEP ONE OUTPUT

	1	2	3	4
NAME	Kendrick	Kendrick	Hunting	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	9	13	13	10
#LT LANES	0	0	0	0
AVG WIDTH	0	0	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	31	838	221	1
THRU VOL	209	699	987	126
RT VOL	1	294	78	130
PED VOL	1	1	1	1
TRUCK %	1.1	0.0	0.4	1.1
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	72	72	72	72
CHANGE INT	50	50	50	50
LT CAP ON CI	100	100	100	100
G/C	.59	.59	.40	.40
OP VOL	993	210	256	1021
LT CAP ON GR	0	499	324	0
LT TOT CAP	100	599	324	100
LT VOL	31	838	221	1
PASS CHK	Yes	No	Yes	Yes

STEP SIX OUTPUT

PHF	0.78	0.93	0.93	0.96
LT VOL	40	901	239	1
THRU VOL	271	752	1061	133
RT VOL	1	316	41	137

STEP SEVEN OUTPUT

OP VOL	993	210	256	1021
PCE LTU	4.00	1.00	1.00	6.00
PCE LTP	1.20	1.20	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	433	320
A2B1 <-- v--	1969	2150
A3B4 v '->	1741	1389
B3A4 <-. ^	276	271

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:07-19-1985 TIME:09:39:36
1995 NO BUILD

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	250	185
A2B1 <-- v--	931	1016
A3B4 v '->	634	656
A4B3 <-, ^	145	142

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

931	1-one phase only
1201	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

634	1-one phase only
799	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1	0.87	1564	1800	D
1*	8	1.01	1739	1720	F
8	1	1.07	1814	1720	F
8	8	1.21	1999	1650	F

* This phasing may be inappropriate due to left turn restrictions see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:07-19-1985 TIME:09:42:01
1995 Service Loop

STEP ONE OUTPUT

	1	2	3	4
NAME	Kendrick	Kendrick	Hunting	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	9	13	13	10
#LT LANES	0	0	0	0
AVG WIDTH	0	0	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	31	838	221	1
THRU VOL	209	699	997	124
RT VOL	1	294	78	130
PED VOL	1	1	1	1
TRUCK %	1.1	0.0	0.1	1.1
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	72	72	72	72
CHANGE INT	50	50	50	50
LT CAP ON CI	100	100	100	100
G/C	.59	.59	.41	.41
OP VOL	993	210	258	1021
LT CAP ON GR	0	498	224	0
LT TOT CAP	100	598	324	100
LT VOL	31	838	221	1
PASS CHK	Yes	No	Yes	Yes

STEP SIX OUTPUT

PHF	0.78	0.93	0.97	0.96
LT VOL	40	901	239	1
THRU VOL	271	752	1061	133
RT VOL	1	316	41	137

STEP SEVEN OUTPUT

OP VOL	993	210	258	1021
PCE LTU	4.00	1.00	1.00	6.00
PCE LTP	1.20	1.20	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	433	320
A2B1 <-- v--	1969	2150
A3B4 v '->	1341	1389
B3A4 <-. ^	276	271

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:07-19-1985 TIME:09:42:29
1995 Service Loop

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	250	185
A2B1 <-- v--	931	1016
A3B4 v '->	634	656
A4B3 <-, ^	145	142

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

931	1-one phase only
1201	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

634	1-one phase only
798	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1	0.87	1564	1800	D
1*	8	1.01	1729	1720	F
8	1	1.07	1834	1730	F
8	8	1.21	1999	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:07-19-1985 TIME:09:44:02
1995 Frontage Road

STEP ONE OUTPUT

	1	2	3	4
NAME	Kendrick	Kendrick	Hunting	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	9	13	13	10
#LT LANES	0	0	0	0
AVG WIDTH	0	0	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	31	937	204	1
THRU VOL	209	782	907	126
RT VOL	1	329	35	130
PED VOL	1	1	1	1
TRUCK %	1.1	0.0	0.4	1.1
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	72	72	72	72
CHANGE INT	50	50	50	50
LT CAP ON CI	100	100	100	100
G/C	.64	.64	.35	.35
OP VOL	1111	210	256	942
LT CAP ON GR	0	558	164	0
LT TOT CAP	100	558	264	100
LT VOL	31	937	204	1
PASS CHK	Yes	No	Yes	Yes

STEP SIX OUTPUT

PHF	0.78	0.93	0.93	0.96
LT VOL	40	1008	220	1
THRU VOL	271	841	979	133
RT VOL	1	354	39	137

STEP SEVEN OUTPUT

OP VOL	1111	210	256	942
PCE LTU	6.00	1.00	1.00	4.00
PCE LTP	1.20	1.20	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	513	320
A2B1 <-- v--	2203	2404
A3B4 v '->	1237	1281
B3A4 <-. ^	274	271

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:07-19-1985 TIME:09:44:30
1995 Frontage Road

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	296	185
A2B1 <-- v--	1041	1136
A3B4 v '->	585	605
A4B3 <-. ^	144	142

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

1041 1-one phase only
1321 8-two phases.directional split

POSSIBLE PHASES APPROACHES 3 & 4

585 1-one phase only
748 8-two phases.directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1	0.90	1625	1800	E
1*	8	1.04	1788	1720	F
8	1	1.11	1906	1720	F
8	8	1.25	2069	1650	F

* This phasing may be inappropriate due to left turn restrictions see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)
DATE:07-19-1985 TIME:09:45:16
1995 Frontage Road/Service Loop

STEP ONE OUTPUT

	1	2	3	4
NAME	Kendrick	Kendrick	Hunting	Hunting
#THRU LANES	2	2	2	2
AVG WIDTH	9	13	13	10
#LT LANES	0	0	0	0
AVG WIDTH	0	0	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	31	937	204	1
THRU VOL	209	782	907	126
RT VOL	1	329	35	130
PED VOL	1	1	1	1
TRUCK %	1.1	0.0	0.4	1.1
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	72	72	72	72
CHANGE INT	50	50	50	50
LT CAP ON CI	100	100	100	100
G/C	.64	.64	.35	.35
OP VOL	1111	210	256	942
LT CAP ON GR	0	558	164	0
LT TOT CAP	100	655	264	100
LT VOL	31	937	204	1
PASS CHK	Yes	No	Yes	Yes

STEP SIX OUTPUT

PHF	0.78	0.93	0.93	0.96
LT VOL	40	1008	220	1
THRU VOL	271	841	979	133
RT VOL	1	354	38	137

STEP SEVEN OUTPUT

OP VOL	1111	210	256	942
PCE LTU	6.00	1.00	1.00	4.00
PCE LTP	1.20	1.20	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	513	320
A2B1 <-- v--	2203	2404
A3B4 v '->	1237	1281
B3A4 <-, ^	274	271

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:07-19-1985 TIME:09:45:37
1995 Frontage Road/Service Loop

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
A1B2 --> --^	296	185
A2B1 <-- v--	1041	1136
A3B4 v '->	585	605
A4B3 <-, ^	144	142

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

1041 1-one phase only
1321 8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

585 1-one phase only
748 8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1	0.90	1625	1800	E
1*	8	1.04	1788	1720	F
8	1	1.11	1906	1710	F
8	8	1.25	2069	1650	F

* This phasing may be inappropriate due to left turn restrictions see STEP FOUR OUTPUT above

Appendix E

Analysis Worksheets for Intersections Unaffected by Frontage Road/Service Road Alternatives

Appendix E

Description of Content

At several study-area intersections, alternative network configurations considered for implementation in the area of the New England Industrial Center would have no effect on the base-network 1995 volume forecasts. This appendix contains the worksheet results for the capacity analysis performed at each of these locations.

The intersections analyzed are:

- Highland Avenue at Webster Street
- Webster Street at Greendale Avenue
- Needham Street at Oak Street and Christina Street
- Needham Street at Winchester Street and Dedham Street
- Winchester Street at Centre Street and EB Route 9 Ramps
- Winchester Street at Centre Street and WB Route 9 Ramps
- Kendrick Street at Greendale Avenue

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)

DATE:10-23-1985 TIME:11:31:36

1995 FRONTAGE ROAD AND SERVICE LOOP ALTERNATIVES WITH EXCLUSIVE LEFT ON HIGHLAND

STEP ONE OUTPUT

	1	2	3	4
NAME	HIGHLAND	HIGHLAND	WEBSTER	WEBSTER
#THRU LANES	2	1	1	2
AVG WIDTH	8	10	13	11
#LT LANES	0	1	0	0
AVG WIDTH	0	10	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	23	520	44	23
THRU VOL	650	764	473	150
RT VOL	25	73	101	197
PED VOL	10	10	10	10
TRUCK %	2.3	1.8	0.4	1.0
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	70	70	70	70
CHANGE INT	51	51	51	51
LT CAP ON CI	103	103	103	103
G/C	.57	.57	.42	.42
OP VOL	837	675	347	574
LT CAP ON GR	0	9	157	0
LT TOT CAP	103	112	260	103
LT VOL	23	520	44	23
PASS CHK	Yes	No	Yes	Yes

STEP SIX OUTPUT

PHF	0.94	0.91	0.89	0.80
LT VOL	25	582	50	29
THRU VOL	707	855	534	189
RT VOL	27	82	114	249

STEP SEVEN OUTPUT

OP VOL	837	675	347	574
PCE LTU	4.00	4.00	2.00	2.00
PCE LTP	1.20	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B1 v--	2327	611
A2 <--	936	936
A1B2 --> --^	835	765
A3B4 v '->	747	707
B3A4 <-, ^	496	473

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2 OF 2)
DATE:10-23-1985 TIME:11:32:05
1995 FRONTAGE ROAD AND SERVICE LOOP ALTERNATIVES WITH EXCLUSIVE LEFT ON HIGHLAND

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B1 v--	2327	611
A2 <--	936	936
A1B2 --> --^	482	442
A3B4 v '->	672	636
A4B3 <-, ^	260	248

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

2327	1-one phase only
1547	2-two phase,one left protected,no overlap
1093	3-two phases,one left protected,overlap
1378	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

672	1-one phase only
885	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
3	1	1.03	1765	1720	F
8	1	1.19	2050	1720	F
3	8	1.20	1978	1650	F
2	1	1.29	2219	1720	F
8	8	1.37	2263	1650	F
2	8	1.47	2432	1650	F
1*	1	1.67	2999	1800	F
1*	8	1.87	3212	1720	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 1 OF 2)

DATE:10-23-1985 TIME:11:39:11

1995 FRONTAGE ROAD AND SERVICE LOOP ALTERNATIVES WITH EXCLUSIVE LEFT A TWO THRU LANES ON HIGHLAND

STEP ONE OUTPUT

	1	2	3	4
NAME	HIGHLAND	HIGHLAND	WEBSTER	WEBSTER
#THRU LANES	2	2	1	2
AVG WIDTH	12	10	13	11
#LT LANES	0	1	0	0
AVG WIDTH	0	10	0	0
#RT LANES	0	0	0	0
AVG WIDTH	0	0	0	0

STEP TWO OUTPUT

LT VOL	23	520	44	23
THRU VOL	650	764	473	150
RT VOL	25	73	101	197
PED VOL	10	10	10	10
TRUCK %	2.3	1.8	0.4	1.0
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	70	70	70	70
CHANGE INT	51	51	51	51
LT CAP ON CI	103	103	103	103
G/C	.45	.45	.54	.54
OP VOL	837	675	347	574
LT CAP ON GR	0	0	301	74
LT TOT CAP	103	103	404	177
LT VOL	23	520	44	23
PASS CHK	Yes	No	Yes	Yes

STEP SIX OUTPUT

PHF	0.94	0.91	0.89	0.80
LT VOL	25	582	50	29
THRU VOL	707	855	534	189
RT VOL	27	82	114	249

STEP SEVEN OUTPUT

OP VOL	837	675	347	574
PCE LTU	4.00	4.00	2.00	2.00
PCE LTP	1.20	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B1 v--	2327	611
A2 <--	936	936
A1B2 --> --^	835	765
A2B4 v '->	747	707
B3A4 <-, ^	496	473

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2 OF 2)
DATE:10-23-1985 TIME:11:39:32
1995 FRONTAGE ROAD AND SERVICE LOOP ALTERNATIVES WITH EXCLUSIVE LEFT A TWO THRU LANES ON HIGHLAND

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B1 v--	2327	611
A2 <--	492	492
A1B2 --> --^	438	401
A3B4 v '->	672	636
A4B3 <-, ^	260	248

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

2327	1-one phase only
1102	2-two phase,one left protected,no overlap
1049	3-two phases,one left protected,overlap
1012	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

672	1-one phase only
885	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
8	1	0.98	1684	1720	E
3	1	1.00	1721	1720	F
2	1	1.03	1774	1720	F
8	8	1.15	1897	1650	F
3	8	1.17	1934	1650	F
2	8	1.20	1987	1650	F
1*	1	1.67	2999	1800	F
1*	8	1.87	3212	1720	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:10-22-1985 TIME:10:23:14
1995 FRONTAGE ROAD AND SERVICE LOOP CONFIGURATIONS

GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 2 LANES

MINOR STREET LANES
APPROACH: C: GREENDALE
SHARED LEFT AND RIGHT TURN LANES: Y

APPROACH	A: WEBSTER			B: WEBSTER			C: GREENDALE		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	337	7	202	770	0	0	0	62
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	98.00			%100.00			98.00		
PERCENT LT TRU	1.00			0.00			1.00		
PERCENT HV TRU	1.00			0.00			1.00		
PASS CAR/HR	0			202			0	0	63

STEP 1 RIGHT TURNS FROM	C:GREENDALE
CONFLICTING FLOWS	341
CRITICAL GAPS	5.0
CAPACITY	856
SHARED LANE	Y

STEP 2 LEFT TURNS FROM	B:WEBSTER
CONFLICTING FLOWS	344
CRITICAL GAPS	5.0
CAPACITY	853
DEMAND	202
CAPACITY USED	24
IMPEDANCE FACTOR	0.83
AVAILABLE RESERVE	651
DELAY	Little or no delay
LOS	A

STEP 3 LEFT TURNS FROM	C:GREENDALE
CONFLICTING FLOWS	1313
CRITICAL GAPS	6.5
CAPACITY	156
ADJUST FOR IMP	129
SHARED LANE RIGHT	Y
SHARED LN DEMAND	63
CAPACITY OF SHARED LN	856
AVAILABLE RESERVE	793
DELAY	Little or no delay
LOS	A

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	202	853	651	A
ALL MOVES FROM C:	63	856	793	A

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:10-22-1985 TIME:08:33:02
1995 FRONTAGE ROAD AND SERVICE LOOP CONFIGURATIONS SIGNAL WITH EXCLUSIVE LEF
NES ON NEEDHAM ASSUME RIGHT TURNS FROM OAK REDUCED BY 15%

STEP ONE OUTPUT

	1	2	3	4
NAME	NEEDHAM	NEEDHAM	OAK	CHRISTINA
#THRU LANES	1	1	1	1
AVG WIDTH	12	12	12	12
#LT LANES	1	1	0	0
AVG WIDTH	12	12	0	0
#RT LANES	0	0	1	0
AVG WIDTH	0	0	10	0

STEP TWO OUTPUT

LT VOL	138	29	125	104
THRU VOL	1121	1116	66	64
RT VOL	54	247	165	57
PED VOL	0	0	0	0
TRUCK %	2.3	2.5	1.2	1.0
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	60	60	60	60
CHANGE INT	60	60	60	60
LT CAP ON CI	120	120	120	120
G/C	.85	.85	.14	.14
OP VOL	1363	1175	121	231
LT CAP ON GR	0	0	47	0
LT TOT CAP	120	120	167	120
LT VOL	138	29	125	104
PASS CHK	No	Yes	Yes	Yes

STEP SIX OUTPUT

PHF	0.87	0.90	0.84	0.72
LT VOL	162	33	151	146
THRU VOL	1318	1271	80	90
RT VOL	63	281	199	80

STEP SEVEN OUTPUT

OP VOL	1363	1175	121	231
PCE LTU	6.00	6.00	1.00	1.00
PCE LTP	1.05	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	974	170
A1 -->	1382	1382
B1 v--	198	35
A2 <--	1552	1552
A3B4 v '->	230	260
B3A4 <-, ^	316	345

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2 OF 2)
DATE:10-22-1985 TIME:08:33:50
1995 FRONTAGE ROAD AND SERVICE LOOP CONFIGURATIONS SIGNAL WITH EXCLUSIVE LEFT LANES ON NEEDHAM ASSUME RIGHT TURNS FROM OAK REDUCED BY 15%

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B2 --^	974	170
A1 -->	1382	1382
B1 v--	198	35
A2 <--	1552	1552
A3B4 v '->	230	260
A4B3 <-, ^	316	345

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

1552	1-one phase only
1723	2-two phase,one left protected,no overlap
1723	3-two phases,one left protected,overlap
1723	4-two phases,both lefts protected,no overlap
1723	5-three phases,both lefts protected,overlap
1757	6-three phases,lead/lag,no overlap
2526	7-three phases,lead/lag,overlap
2934	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

316	1-one phase only
605	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1	1.04	1868	1800	F
3	1	1.19	2038	1720	F
4	1	1.19	2038	1720	F
2	1	1.19	2038	1720	F
5	1	1.24	2038	1650	F
1*	8	1.25	2157	1720	F
6	1	1.26	2073	1650	F
5	8	1.41	2328	1650	F
3	8	1.41	2328	1650	F
4	8	1.41	2328	1650	F
2	8	1.41	2328	1650	F
6	8	1.43	2362	1650	F
7	1	1.72	2842	1650	F
8	1	1.89	3250	1720	F
7	8	1.90	3131	1650	F
8	8	2.14	3539	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)

DATE:10-22-1985 TIME:08:37:59

1995 FRONTAGE ROAD AND SERVICE LOOP ALTERNATIVES SIGNAL WITH EXCLUSIVE LEFT TWO THRU LANES ON EACH NEEDHAM APPROACH ASSUME ASSUME RIGHT TURNS FROM OAK UCED BY 15%

STEP ONE OUTPUT

	1	2	3	4
NAME	NEEDHAM	NEEDHAM	OAK	CHRISTINA
#THRU LANES	2	2	1	1
AVG WIDTH	12	12	12	12
#LT LANES	1	1	0	0
AVG WIDTH	12	12	0	0
#RT LANES	0	0	1	0
AVG WIDTH	0	0	10	0

STEP TWO OUTPUT

LT VOL	138	29	125	104
THRU VOL	1121	1116	66	64
RT VOL	54	247	165	57
PED VOL	0	0	0	0
TRUCK %	2.3	2.5	1.2	1.0
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	60	60	60	60
CHANGE INT	60	60	60	60
LT CAP ON CI	120	120	120	120
G/C	.75	.75	.24	.24
OP VOL	1363	1175	121	231
LT CAP ON GR	0	0	167	57
LT TOT CAP	120	120	287	177
LT VOL	138	29	125	104
PASS CHK	No	Yes	Yes	Yes

STEP SIX OUTPUT

PHF	0.87	0.90	0.84	0.72
LT VOL	162	33	151	146
THRU VOL	1318	1271	80	90
RT VOL	63	281	199	80

STEP SEVEN OUTPUT

OP VOL	1363	1175	121	231
PCE LTU	6.00	6.00	1.00	1.00
PCE LTP	1.05	1.05	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	974	170
A1 -->	1382	1382
B1 v--	198	35
A2 <--	1552	1552
A3B4 v '->	230	260
B3A4 <-, ^	316	345

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2 OF 2)
DATE:10-22-1985 TIME:08:38:27
1995 FRONTAGE ROAD AND SERVICE LOOP ALTERNATIVES SIGNAL WITH EXCLUSIVE LEFT AND TWO THRU LANES ON EACH NEEDHAM APPROACH ASSUME ASSUME RIGHT TURNS FROM OAK REDUCED BY 15%

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B2 --^	974	170
A1 -->	725	725
B1 v--	198	35
A2 <--	815	815
A3B4 v '->	230	260
A4B3 <-, ^	316	345

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

974	1-one phase only
985	2-two phase,one left protected,no overlap
985	3-two phases,one left protected,overlap
985	4-two phases,both lefts protected,no overlap
985	5-three phases,both lefts protected,overlap
1020	6-three phases,lead/lag,no overlap
1789	7-three phases,lead/lag,overlap
1540	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

316	1-one phase only
605	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1	0.72	1289	1800	C
3	1	0.76	1301	1720	C
4	1	0.76	1301	1720	C
2	1	0.76	1301	1720	C
5	1	0.79	1301	1650	D
6	1	0.81	1336	1650	D
1*	8	0.92	1579	1720	E
2	8	0.96	1590	1650	E
5	8	0.96	1590	1650	E
4	8	0.96	1590	1650	E
3	8	0.96	1590	1650	E
6	8	0.98	1625	1650	E
8	1	1.08	1856	1720	F
7	1	1.28	2104	1650	F
8	8	1.30	2145	1650	F
7	8	1.45	2394	1650	F

* This phasing may be inappropriate due to left turn restrictions see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2)
DATE:10-22-1985 TIME:09:05:56
1995 CONFIGURATIONS DOUBLE LEFT TURN LANES ON NEEDHAM IN ADDITION TO TOPICS OVEMENTS

STEP ONE OUTPUT

	1	2	3	4
NAME	NEEDHAM	DEDHAM	WINCHESTER	WINCHESTER
#THRU LANES	1	2	1	2
AVG WIDTH	10	8	13	8
#LT LANES	2	0	0	0
AVG WIDTH	10	0	0	0
#RT LANES	1	0	1	0
AVG WIDTH	15	0	13	0

STEP TWO OUTPUT

LT VOL	1257	22	176	24
THRU VOL	180	93	258	307
RT VOL	0	116	0	7
PED VOL	0	0	0	0
TRUCK %	0.6	0.6	2.0	0.0
BUS STOP	0	0	0	0

STEP FOUR OUTPUT

CYCLE(secs)	60	60	60	60
CHANGE INT	60	60	60	60
LT CAP ON CI	120	120	120	120
G/C	.70	.70	.30	.30
OP VOL	209	180	314	258
LT CAP ON GR	631	660	46	102
LT TOT CAP	751	780	166	222
LT VOL	1257	22	176	24
PASS CHK	No	Yes	No	Yes

STEP SIX OUTPUT

PHF	0.93	0.84	0.92	0.73
LT VOL	1360	26	195	33
THRU VOL	195	111	286	421
RT VOL	0	139	0	10

STEP SEVEN OUTPUT

OP VOL	209	180	314	258
PCE LTU	1.00	1.00	2.00	1.00
PCE LTP	1.05	1.20	1.20	1.20
PCE RT	1.00	1.00	1.00	1.00

	UNPROTECT LT	PROTECT LT
B2 --^	1360	1428
A1 -->	195	195
A2B1 <-- v--	277	282
A3B4 v '->	676	520
B3A4 <-, ^	463	470

CIRCULAR 212 WORKSHEET: SIGNALIZED INTERSECTION - OPERATIONS & DESIGN (PAGE 2 OF 2)
DATE:10-22-1985 TIME:09:07:08
1995 CONFIGURATIONS DOUBLE LEFT TURN LANES ON NEEDHAM IN ADDITION TO TOPICS IMPROVEMENTS

STEP EIGHT AND NINE A OUTPUT

	UNPROTECT LT	PROTECT LT
B2 --^	714	750
A1 -->	195	195
A2B1 <-- v--	160	163
A3B4 v *->	609	468
A4B3 <-, ^	267	271

STEP TEN OUTPUT

POSSIBLE PHASES APPROACHES 1 & 2

714	1-one phase only
944	2-two phase,one left protected,no overlap
912	3-two phases,one left protected,overlap
912	8-two phases,directional split

POSSIBLE PHASES APPROACHES 3 & 4

609	1-one phase only
739	8-two phases,directional split

Phasing 1&2	Phasing 3&4	v/c	SUM CV	Capacity	LOS
1*	1*	0.73	1323	1800	C
1*	8	0.84	1453	1720	D
8	1*	0.88	1521	1720	D
3	1*	0.88	1521	1720	D
2	1*	0.90	1553	1720	E
8	8	1.00	1652	1650	F
3	8	1.00	1652	1650	F
2	8	1.02	1684	1650	F

* This phasing may be inappropriate due to left turn restrictions
see STEP FOUR OUTPUT above

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:01-01-1980 TIME:00:20:28
1995 ALTERNATE AND NO BUILD CONFIGURATIONS WITH GEOMETRIC IMPROVEMENTS

GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 4 LANES

MINOR STREET LANES
APPROACH: C: EB RAMP
SHARED LEFT AND RIGHT TURN LANES: N

APPROACH	A: WINCHESTER			B: CENTRE			C: EB RAMP		
	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	0	1456	441	256	1267	0	81	0	233
PERCENT GRADE	0.00			0.00			0.00		
PERCENT CYCLES	0.00			0.00			0.00		
PASSENGER CARS	95.00			98.00			%100.00		
PERCENT LT TRU	2.00			1.00			0.00		
PERCENT HV TRU	3.00			1.00			0.00		
PASS CAR/HR	0			260			81	0	233

STEP 1 RIGHT TURNS FROM	C:EB RAMP
CONFLICTING FLOWS	949
CRITICAL GAPS	5.0
CAPACITY	451
DEMAND	233
SHARED LANE	N
AVAILABLE RESERVE	218
DELAY	Average delay
LOS	C

STEP 2 LEFT TURNS FROM	B:CENTRE
CONFLICTING FLOWS	1897
CRITICAL GAPS	5.5
CAPACITY	123
DEMAND	260
CAPACITY USED	211
IMPEDANCE FACTOR	0.00
AVAILABLE RESERVE	-137
DELAY	Failure
LOS	E*

STEP 3 LEFT TURNS FROM	C:EB RAMP
CONFLICTING FLOWS	3200
CRITICAL GAPS	7.0
CAPACITY	8
ADJUST FOR IMP	0
SHARED LANE RIGHT	N
DEMAND	81
AVAILABLE RESERVE	-81
DELAY	Failure
LOS	E*

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

MOVEMENT	DEMAND	CAPACITY	RESERVE	LOS
LT FROM B:	260	123	-137	E*
LT FROM C:	81	8	-81	E*
RT FROM C:	233	451	218	C

CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 4 APPROACHES (PAGE 1 OF 2)
DATE:01-01-1980 TIME:00:08:41
1995 ALTERNATE AND NO BUILD CONFIGURATIONS WITH EXCLUSIVE LEFT AND RIGHT LAN
N WB OFF RAMP
GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 2 LANES

MINOR STREET LANES
APPROACH: C: 9 WB OFF
EXCLUSIVE LEFT TURN LANES: Y
EXCLUSIVE RIGHT TURN LANES: Y

APPROACH: D: 9 ON RAMP
EXCLUSIVE LEFT TURN LANES: Y
EXCLUSIVE RIGHT TURN LANES: Y

APPROACH	A: WINCHESTER			B: CENTRE			C: 9 WB OFF			D: 9 ON RAMP		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
VOLUME	245	1457	0	0	1183	167	146	2	163	3	0	122
PERCENT GRADE	0.00			0.00			0.00					
PERCENT CYCLES	0.00			0.00			0.00			0.00		
PASSENGER CARS	97.00			99.00			97.00			99.00		
PERCENT LT TRU	1.00			0.00			1.00			0.00		
PERCENT HV TRU	2.00			1.00			2.00			1.00		
PASS CAR/HR	251			0			150	2	167	3	0	123

STEP 1 RIGHT TURNS FROM	C:9 WB OFF	D:9 ON RAMP
CONFLICTING FLOWS	729	1267
CRITICAL GAPS	5.0	5.0
CAPACITY	569	322
DEMAND	167	123
CAPACITY USED	29	38
IMPEDANCE FACTOR	0.78	0.69
SHARED LANE	N	N
AVAILABLE RESERVE	401	199
DELAY	Little or no delay	Long delay
LOS	A	D

STEP 2 LEFT TURNS FROM	B:CENTRE	A:WINCHESTER
CONFLICTING FLOWS	1457	1350
CRITICAL GAPS	5.0	5.0
CAPACITY	264	295
DEMAND	0	251
CAPACITY USED	0	85
IMPEDANCE FACTOR	1.00	0.20
AVAILABLE RESERVE	264	44
DELAY	Average delay	Very long delay
LOS	C	E

RCULAR 212 WORKSHEET: UNSIGNALIZED - 4 APPROACHES (PAGE 2 OF 2)
TE:01-01-1980 TIME:00:08:52
995 ALTERNATE AND NO BUILD CONFIGURATIONS WITH EXCLUSIVE LEFT AND RIGHT LANES O
WB OFF RAMP

TEP 3 THRU MOVES FROM	C:9 WB OFF	D:9 ON RAMP
ONFLICTING FLOWS	3052	2969
RITICAL GAPS	6.0	6.0
APACITY	21	24
DJUST FOR IMP	4	5
EMAND	2	0
APACITY USED	49	0
MPEDANCE FACTOR	0.59	1.00
HARED LANE LEFT	N	N
HARED LANE RIGHT	N	N
VAILABLE RESERVE	2	5
ELAY	Very long delay	Very long delay
OS	E	E

TEP 4 LEFT TURNS FROM	C:9 WB OFF	D:9 ON RAMP
ONFLICTING FLOWS	3174	3134
RITICAL GAPS	6.5	6.5
APACITY	12	13
DJUST FOR IMP	2	1
HARED LANE THRU	N	N
HARED LANE RIGHT	N	N
EMAND	150	3
VAILABLE RESERVE	-148	-2
ELAY	Failure	Failure
OS	E*	E*

SUMMARY OF LEVEL OF SERVICE BY MOVEMENT

OVEMENT	DEMAND	CAPACITY	RESERVE	LOS
T FROM A:	251	295	44	E
T FROM C:	150	2	-148	E*
H FROM C:	2	4	2	E
T FROM C:	167	569	401	A
T FROM D:	3	1	-2	E*
T FROM D:	123	322	199	D

```
CIRCULAR 212 WORKSHEET: UNSIGNALIZED - 3 APPROACHES
DATE:07-20-1995                TIME:08:29:54
1995 NO BUILD

GENERAL CHARACTERISTICS
CONTROLS: YIELD
PREVAILING SPEED: 30 MPH
MAIN STREET # OF LANES: 2 LANES

MINOR STREET LANES
APPROACH: C: Kendrick
SHARED LEFT AND RIGHT TURN LANES: Y


APPROACH          A: Greendale    B: Greendale    C: Kendrick
                   LT   TH   RT    LT   TH   RT    LT   TH   RT
VOLUME              0   67    0     0  148    0    22    0  670
PERCENT GRADE      0.00            0.00            0.00
PERCENT CYCLES      0.00            0.00            0.00
PASSENGER CARS     98.00           99.00           99.00
PERCENT LT TRU      1.00            0.00            0.00
PERCENT HV TRU      1.00            1.00            1.00
PASS CAR/HR         0               0              22    0  677


STEP 1 RIGHT TURNS FROM      C:Kendrick
CONFLICTING FLOWS                    67
CRITICAL GAPS                       5.0
CAPACITY                           1142
SHARED LANE                           Y


STEP 2 LEFT TURNS FROM       B:Greendale
CONFLICTING FLOWS                    67
CRITICAL GAPS                       5.0
CAPACITY                           1142
DEMAND                                0
CAPACITY USED                         0
IMPEDANCE FACTOR                   1.00
AVAILABLE RESERVE                  1142
DELAY                    Little or no delay
LOS                                   A


STEP 3 LEFT TURNS FROM       C:Kendrick
CONFLICTING FLOWS                   215
CRITICAL GAPS                       6.5
CAPACITY                            702
ADJUST FOR IMP                      702
SHARED LANE RIGHT                     Y
SHARED LN DEMAND                    699
CAPACITY OF SHARED LN              1120
AVAILABLE RESERVE                   421
DELAY                    Little or no delay
LOS                                   A


                    SUMMARY OF LEVEL OF SERVICE BY MOVEMENT
MOVEMENT              DEMAND     CAPACITY   RESERVE    LOS

ALL MOVES FROM C:        699         1120        421      A
```

Appendix F

Analysis Worksheets for Needham Street

Arterial Section Evaluation

Appendix F

Description of Content

Needham Street segments between selected intersections and driveway curb-cuts were analyzed using 1985 Highway Capacity Manual methods cited in section 4.2.3. The analysis was performed to evaluate the effect which curb-cut closings would have on speed and delay parameters. Curb-cut elimination in conjunction with an internal circulation system off Needham Street is proposed for implementation by the City of Newton and Needham Street property owners to maintain adequate traffic flow in future years.

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Winchester St. to Columbia Rd.
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 1:25 PM
DATE OF ANALYSIS: 9-10-86
MISC. INFO: PRESENT CONDITION

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: WESTBOUND

WEST
INTER 1 ----------> INTER 9

CYCLE LENGTH (sec): 90
NO. OF SEGMENTS: 8

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	3.9	A	5.1
2	0	0	0	1	4.8	A	6.2
3	0	0	0	1	4.8	A	6.2
4	0	0	0	1	3.6	A	4.7
5	0	0	0	1	3.6	A	4.7
6	0	0	0	1	3.6	A	4.7
7	0	0	0	1	4.8	A	6.2
8	0	0	0	1	3.6	A	4.7

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	DELAY/TIME RUN TIME	DELAY/TIME OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	5.1	4.9	0	.026	35	III	9.4	D
2	6.2	4.9	0	.026	35	III	8.4	E
3	6.2	4.9	0	.026	35	III	8.4	E
4	4.7	4.9	0	.026	35	III	9.8	D
5	4.7	4.9	0	.026	35	III	9.8	D
6	4.7	4.9	0	.026	35	III	9.8	D
7	6.2	4.9	0	.026	35	III	8.4	E
8	4.7	4.9	0	.026	35	III	9.8	D

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec): 81.7
SUM OF LENGTH (mi): .208
ARTERIAL CLASS: III
AVERAGE SPEED (mph): 9.2
LOS: D

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Columbia Rd. to Railroad Tracts
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 2:05 PM
DATE OF ANALYSIS: 9-10-86
MISC.INFO: PRESENT CONDITION

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: WESTBOUND

WEST
INTER 1 ----------> INTER 7

CYCLE LENGTH (sec): 90
NO. OF SEGMENTS: 6

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	3.6	A	4.7
2	0	0	0	1	5.8	B	7.5
3	0	0	0	1	4.3	A	5.6
4	0	0	0	1	3.6	A	4.7
5	0	0	0	1	3.6	A	4.7
6	0	0	0	1	3.6	A	4.7

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	DELAY/TIME RUN TIME	DELAY/TIME OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	4.7	6.1	0	.033	35	III	11	D
2	7.5	6.1	0	.033	35	III	8.7	E
3	5.6	6.1	0	.033	35	III	10.2	D
4	4.7	6.1	0	.033	35	III	11	D
5	4.7	6.1	0	.033	35	III	11	D
6	4.7	6.1	0	.033	35	III	11	D

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec):	68.5
SUM OF LENGTH (mi):	.198
ARTERIAL CLASS:	III
AVERAGE SPEED (mph):	10.4
LOS:	D

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Railroad Tracks to Christina St.
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 2:15 PM
DATE OF ANALYSIS: 9-10-86
MISC.INFO: PRESENT CONDITION

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: WESTBOUND

WEST
INTER 1 ---------> INTER 9

CYCLE LENGTH (sec): 90
NO. OF SEGMENTS: 8

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	4.3	A	5.6
2	0	0	0	1	4.3	A	5.6
3	0	0	0	1	4.3	A	5.6
4	0	0	0	1	3.9	A	5.1
5	0	0	0	1	3.6	A	4.7
6	0	0	0	1	5.8	B	7.5
7	0	0	0	1	5.8	B	7.5
8	0	0	0	1	5.7	B	7.4

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	RUN TIME	OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	5.6	5.2	0	.028	35	III	9.3	D
2	5.6	5.2	0	.028	35	III	9.3	D
3	5.6	5.2	0	.028	35	III	9.3	D
4	5.1	5.2	0	.028	35	III	9.8	D
5	4.7	5.2	0	.028	35	III	10.2	D
6	7.5	5.2	0	.028	35	III	7.9	E
7	7.5	5.2	0	.028	35	III	7.9	E
8	7.4	5.2	0	.028	35	III	8	E

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec): 59999
SUM OF LENGTH (mi): .224
ARTERIAL CLASS: III
AVERAGE SPEED (mph): 8.9
LOS: E

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Christina St. to Railroad Tracks
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 2:25 PM
DATE OF ANALYSIS: 9-10-86
MISC.INFO: PRESENT CONDITION

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: EASTBOUND

EAST
INTER 1 ----------> INTER 9

CYCLE LENGTH (sec): 90
NO. OF SEGMENTS: 8

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	3.9	A	5.1
2	0	0	0	1	3.9	A	5.1
3	0	0	0	1	5.8	B	7.5
4	0	0	0	1	5.8	B	7.5
5	0	0	0	1	3.9	A	5.1
6	0	0	0	1	4.8	A	6.2
7	0	0	0	1	5.8	B	7.5
8	0	0	0	1	3.9	A	5.1

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	RUN TIME	OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	5.1	5.2	0	.028	35	III	9.8	D
2	5.1	5.2	0	.028	35	III	9.8	D
3	7.5	5.2	0	.028	35	III	7.9	E
4	7.5	5.2	0	.028	35	III	7.9	E
5	5.1	5.2	0	.028	35	III	9.8	D
6	6.2	5.2	0	.028	35	III	8.8	E
7	7.5	5.2	0	.028	35	III	7.9	E
8	5.1	5.2	0	.028	35	III	9.8	D

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec): 90.7
SUM OF LENGTH (mi): .224
ARTERIAL CLASS: III
AVERAGE SPEED (mph): 8.9
LOS: E

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Railroad Tracks to Columbia Rd.
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 2:10 PM
DATE OF ANALYSIS: 9-10-86
MISC.INFO: PRESENT CONDITION

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: EASTBOUND

EAST
INTER 1 ----------> INTER 8

CYCLE LENGTH (sec): 90
NO. OF SEGMENTS: 7

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	3.9	A	5.1
2	0	0	0	1	3.9	A	5.1
3	0	0	0	1	3.9	A	5.1
4	0	0	0	1	5.8	B	7.5
5	0	0	0	1	3.9	A	5.1
6	0	0	0	1	3.9	A	5.1
7	0	0	0	1	4.8	A	6.2

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	RUN TIME	OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	5.1	6.1	0	.033	35	III	10.6	D
2	5.1	6.1	0	.033	35	III	10.6	D
3	5.1	6.1	0	.033	35	III	10.6	D
4	7.5	6.1	0	.033	35	III	8.7	E
5	5.1	6.1	0	.033	35	III	10.6	D
6	5.1	6.1	0	.033	35	III	10.6	D
7	6.2	6.1	0	.033	35	III	9.7	D

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec): 89999
SUM OF LENGTH (mi): .231
ARTERIAL CLASS: III
AVERAGE SPEED (mph): 10.2
LOS: D

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham ST. - Columbia Road to Winchester St.
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 3:57 PM
DATE OF ANALYSIS: 9-10-86.
MISC.INFO: PRESENT CONDITION

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: EASTBOUND

EAST
INTER 1 ---------> INTER 8

CYCLE LENGTH (sec): 83
NO. OF SEGMENTS: 7

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	3.9	A	5.1
2	0	0	0	1	3.6	A	4.7
3	0	0	0	1	4.8	A	6.2
4	0	0	0	1	3.6	A	4.7
5	0	0	0	1	3.6	A	4.7
6	0	0	0	1	8.2	B	10.7
7	0	0	0	1	26.3	D	34.2

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	RUN TIME	OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	5.1	5.6	0	.03	35	III	10.1	D
2	4.7	5.6	0	.03	35	III	10.5	D
3	6.2	5.6	0	.03	35	III	9.2	D
4	4.7	5.6	0	.03	35	III	10.5	D
5	4.7	5.6	0	.03	35	III	10.5	D
6	10.7	5.6	0	.03	35	III	6.6	F
7	34.2	5.6	0	.03	35	III	2.7	F

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec):	109.5
SUM OF LENGTH (mi):	.21
ARTERIAL CLASS:	III
AVERAGE SPEED (mph):	6.9
LOS:	F

1985 HCM: ARTERIALS 1

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Columbia Rd. to Winchester St.
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 3:50 PM
DATE OF ANALYSIS: 9-10-86
MISC.INFO: CURB-CUTS CLOSED

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: EASTBOUND

EAST
INTER 1 ----------> INTER 2

CYCLE LENGTH (sec): 83
NO. OF SEGMENTS: 1

SEGMENT	g/C	X	CAPACITY	PROG FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	0	1	

B) ARTERIAL ANALYSIS: EA

SEGMENT	DELAY/TIME				LOS
					*******
				III	9.2	D

ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec): 78
SUM OF LENGTH (mi): .2
ARTERIAL CLASS: III
AVERAGE SPEED (mph): 9.2
LOS: D

FEDERAL HIGHWAY ADMINISTRATION

ANALYSIS LOCATION: Needham St. - Railroad Tracks to Oak St.
NAME OF ANALYST: WTS
TIME OF ANALYSIS: 3:55 PM
DATE OF ANALYSIS: 9-10-86
MISC.INFO: CURR CUTS CLOSED

A) INTERSECTION DATA

DIRECTION OF ANALYSIS: EASTBOUND

~~EAST~~ WEST

INTER 1 ----------> INTER 2

CYCLE LENGTH (sec): 90
NO. OF SEGMENTS: 1

SEGMENT	g/C	X	CAPACITY	PROG. FACTOR	INTER. STOP'D DELAY	LOS	APPR. DELAY
1	0	0	0	1	40	D	52

B) ARTERIAL ANALYSIS RESULTS

SEGMENT	DELAY/TIME APPR.	RUN TIME	OTHER	SEGMENT LENGTH	FREE FLOW SPEED	ART'L CLASS	AVG. TRAVEL SPEED	SEGMENT LOS
1	52	28.3	0	.224	35	III	10	D

OVERALL ARTERIAL RESULTS SUMMARY

SUM OF TIME (sec): 80.3
SUM OF LENGTH (mi): .224
ARTERIAL CLASS: III
AVERAGE SPEED (mph): 10
LOS: D